Report of the Sixth Commonwealth Entomological Conference

7th-16th July

1954

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COMMONWEALTH INSTITUTE OF BIOLOGICAL CONTROL
IMPERIAL COLLEGE
FIELD STATION
SILWOOD PARK
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LONDON
COMMONWEALTH INSTITUTE OF ENTOMOLOGY
41 QUEEN'S GATE S.W. 7
DECEMBER, 1954

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Commonwealth Agricultural Bureaux

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Conference

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CONTENTS

PAGE

Foreword iv

Report of the Sixth Commonwealth Entomological Conference, 7th–16th July, 1954 1

Conclusions and Resolutions 10

Appendix I. Memorandum on the Work of the Commonwealth Institute of Entomology from 1st April, 1948 to 31st March, 1954 14

Appendix II. Memorandum on the History and Work of the Commonwealth Institute of Biological Control 22

Appendix III. Proceedings of Committees

A. General Committee 27

B. Committee on Taxonomy 33

Appendix IV. Proceedings of the Open Meetings 34

Appendix V. Memoranda submitted in connection with Open Meetings

A. Memorandum on Commonwealth Resources for the Identification of Insects of Economic Importance 151

B. Memorandum on the Gall Midges living on the Sorghums, the Panicum Millets and Rice, by H. F. Barnes 155

Appendix VI. Reviews of Work in Economic Entomology in the Commonwealth, 1948–54.. 161

FOREWORD

By W. F. C. Morton

Chairman of the Executive Council of the Commonwealth Agricultural Bureaux

It is six years since the last Commonwealth Entomological Conference was held and each successive Conference in the past has stressed the value of such gatherings at periodic intervals. Apart from the benefit of bringing together entomologists from all parts of the Commonwealth for discussions on problems of mutual interest, they provide an opportunity for detailed consideration of the work carried out on behalf of the contributing Governments by the Commonwealth Institute of Entomology and, what is very important, of renewing the personal contacts between the staff and oversea entomologists. It was therefore gratifying that there should have been 55 official delegates or 7 more than at the previous Conference in 1948.

On this occasion the Director of the Commonwealth Institute of Biological Control was present and it gave him an opportunity of discussing with the delegates technical matters relating to his Institute.

It was a disappointment to me that I was unavoidably prevented from being present, but I have been told that the Conference was most successful and the present Report bears this out. The open meetings, I understand, were extremely well attended and valuable discussions took place on the papers that were presented. These papers together with a summary of the discussions are set out in the report. In addition, for the first time, the Reviews of Work in Economic Entomology in the Commonwealth have been printed in the Report, which is in consequence three times as large as that for the 1948 Conference. It is hoped that this overall picture of the developments that have taken place in the Commonwealth over the past six years will prove of real value.

Two Committees were formed, which dealt very fully with the matters laid before them. Many resolutions, some of far-reaching importance, were adopted by the Conference, embodying the recommendations forwarded by the Committees, and these will receive the early and careful consideration of the Executive Council.

W. F. C. Morton,
Chairman of the Executive Council,
Commonwealth Agricultural Bureaux.

REPORT

OF THE

Sixth Commonwealth Entomological Conference

7th-16th July, 1954

Calling of the Conference

The Fifth Commonwealth Entomological Conference, at its final meeting on 30th July, 1948, passed the following resolution:—

> " The Conference endorses the opinion expressed at previous Imperial Entomological Conferences as to the value of periodic meetings of entomologists and recommends that steps be taken in due course for a Sixth Commonwealth Entomological Conference to be held in 1953, of which long notice should be given, the place to be decided by the Executive Council of the Commonwealth Agricultural Bureaux."

It was found desirable for a number of reasons to delay the calling of the Conference until 1954, and invitations were conveyed in May 1953 to the Governments of the Commonwealth countries to send delegates to a Conference to be held in London from 7th to 16th July, 1954.

List of Delegates and Observers

The following official delegates attended:—

Australia.
    Mr. I. F. B. Common.
    Prof. O. W. Tiegs, F.R.S.

Barbados.
    Mr. R. W. E. Tucker.

Canada.
    Mr. A. B. Baird.
    Dr. F. T. Bird.
    Mr. A. D. Pickett.

Ceylon.
    Mr. D. V. W. Abeygunawardena.

Colonial Office.
    Sir Geoffrey Clay, K.C.M.G., O.B.E., M.C.
    Dr. R. A. E. Galley.
    Mr. D. Rhind, O.B.E.
    Prof. O. W. Richards.
    Dr. T. H. C. Taylor.
    Dr. B. P. Uvarov, C.M.G., F.R.S.

Gold Coast.
    Mr. J. Bowden.
    Mr. J. Nicol (West African Cacao Research Institute).
    Mr. B. J. A. Nowosielski Slepowron.

India.
    Dr. E. S. Narayanan.
    Dr. G. A. Patel.

Ireland.
  Dr. J. Carroll.

Jamaica.
  Mr. H. C. James.

Kenya.
  Dr. R. H. Le Pelley.
  Dr. R. C. Rainey (East Africa High Commission).
  Mr. W. A. Sands (East Africa High Commission).

Mauritius.
  Dr. R. Mamet.

New Zealand.
  Mr. B. B. Given.

Nigeria.
  Mr. J. T. Davey.
  Dr. T. A. M. Nash, O.B.E. (West African Institute for Trypanosomiasis Research).
  Dr. J. M. Waterston.

Northern Rhodesia.
  Mr. G. G. Robinson.

Nyasaland.
  Dr. Kate Salmond.

Pakistan.
  Dr. Taskhir Ahmad.

Southern Rhodesia.
  Mr. J. A. Whellan.

Tanganyika.
  Dr. C. H. N. Jackson (East Africa High Commission).
  Mr. A. J. Jones.

Trinidad.
  Mr. M. H. Breese (Imperial College of Tropical Agriculture).
  Prof. T. W. Kirkpatrick (Imperial College of Tropical Agriculture).

Uganda.
  Mr. T. E. T. Trought.

United Kingdom.
  Mr. W. P. L. Cameron.
  Mr. R. Chamberlain.
  Mr. D. Bevan.
  Dr. J. W. Evans.
  Dr. R. C. Fisher.
  Mr. D. W. Hall.
  Mr. G. V. B. Herford, O.B.E.
  Dr. G. D. Morison.
  Dr. I. Thomas.
  Mr. H. W. Thompson.
  Prof. V. B. Wigglesworth, C.B.E., F.R.S.
  Dr. C. B. Williams, F.R.S.
  Dr. D. W. Williams.

Zanzibar.
  Dr. F. L. Vanderplank.

In addition the following attended as observers:—

Nigeria.

Mr. R. J. Kernaghan (Sleeping Sickness Service, Northern Nigeria).

United Kingdom.

Dr. K. R. S. Morris (Nature Conservancy).

United Nations.

Dr. C. Logothetis (Food and Agriculture Organization).

Dr. W. R. Thompson, F.R.S., attended as Director of the Commonwealth Institute of Biological Control.

Programme

The programme was as follows:—

Wednesday, 7th July

10.30 a.m. Opening Plenary Session of Delegates presided over by Lt.-Col. J. G Robertson, B.S.A., F.R.S.A., F.A.I.C. (*Canada*), Acting Vice-Chairman of the Executive Council of the Commonwealth Agricultural Bureaux.

3.30 p.m. Reception for the Delegates by the Trustees and Director at the British Museum (Natural History), Cromwell Road, S.W.7.

Thursday, 8th July

10 a.m. Open Meeting: " Recent Developments in the Use of Insecticides on Field Crops."

Chairman: Sir Geoffrey Clay, K.C.M.G., O.B.E., M.C.

Speaker: Dr. H. G. H. Kearns, O.B.E.

11.30 a.m. Open Meeting: " Recent Developments in the Use of Insecticides from Aircraft."

Chairman: Dr. R. A. E. Galley.

Speakers: Mr. D. Yeo (*Tanganyika*).
Dr. R. C. Rainey (*Kenya*).

2.15 p.m. Open Meeting: " Effect of the Use of Chemicals on the Balance of Animal Populations."

Chairman: Mr. A. D. Pickett (*Canada*).

Speaker: Dr. A. M. Massee, O.B.E.

4 p.m. Open Meeting: " The Development of Resistance to Insecticides."

Chairman: Prof. V. B. Wigglesworth, C.B.E., F.R.S.

Speaker: Dr. J. R. Busvine.

Friday, 9th July

10 a.m. Open Meeting: " The Supply and Training of Taxonomists."

Chairman: Mr. N. D. Riley, C.B.E.

Speaker: Dr. W. J. Hall, C.M.G., M.C.

11.30 a.m. Open Meeting: " The Estimation of real Losses from Insect Pests."

Chairman: Dr. R. H. Le Pelley (*Kenya*).

Speakers: Dr. I. Thomas.
Mr. A. H. Strickland.
Mr. Q. A. Geering (*Uganda*).

2.30 p.m. Meeting of the Committee on Taxonomy.

Saturday, 10th July

Visit to Rothamsted Experimental Station, Harpenden

Monday, 12th July

9.30 a.m. First Meeting of General Committee.

2.15 p.m. Open Meeting: "The Biological Control of Insect Pests."
Chairman: Prof. O. W. Richards.
Speaker: Dr. W. R. Thompson, F.R.S.

4 p.m. Open Meeting: "The Biological Control of Weeds."
Chairman: Mr. B. B. Given (*New Zealand*).
Speaker: Mr. J. R. Williams—paper read by Dr. R. Mamet (*Mauritius*).

Tuesday, 13th July

10 a.m. Open Meeting: "Some Pests of Tropical Cereal Crops."
Chairman: Mr. D. Rhind, O.B.E.
Speakers: Dr. H. F. Barnes.
Mr. J. Bowden (*Gold Coast*).

11.30 a.m. Open Meeting: "Development in Work on Pests of Stored Products."
Chairman: Prof. J. W. Munro, C.B.E.
Speaker: Mr. G. V. B. Herford, O.B.E.

2.15 p.m. Open Meeting: "Problems of Forest Entomology."
Chairman: Mr. F. S. Collier, C.B.E.
Speakers: Dr. R. C. Fisher.
Dr. F. T. Bird (*Canada*).

4 p.m. Open Meeting: "Developments in Termite Research."
Chairman: Prof. T. W. Kirkpatrick (*Trinidad*).
Speaker: Mr. W. V. Harris.

8.30 p.m. Reception for the Delegates given by the President and Council of the Royal Entomological Society of London, at 41 Queen's Gate, S.W.7.

Wednesday, 14th July

Visits to the Field Station of the Imperial College of Science and Technology, at Silwood Park, Sunninghill and to the Pest Infestation Laboratory of the Department of Scientific and Industrial Research, at Slough.

Thursday, 15th July

9.30 a.m. Second Meeting of General Committee.

2.15 p.m. Open Meeting: "Developments in Locust and Grasshopper Research and Control."
Chairman: Prof. O. W. Tiegs, F.R.S. (*Australia*)
Speakers: Mr. L. G. Putman—paper read by Mr. A. B. Baird (*Canada*).
Dr. B. P. Uvarov, C.M.G., F.R.S.

4 p.m. Open Meeting: "Recent Developments in Tsetse Research and Control."
Chairman: Prof. P. A. Buxton, C.M.G., F.R.S.
Speaker: Dr. C. H. N. Jackson (*Tanganyika*).

Evening. Official Reception and Supper to the Delegates given by Her Majesty's Government, at Hampton Court Palace.

Friday, 16th July

10 a.m. Final Meeting of General Committee.
3 p.m. Closing Plenary Session of Delegates.

Place of Meetings

By the courtesy of the President and Council of the Royal Entomological Society of London, the plenary sessions of the Conference and the meetings of committees were held, respectively, in the Meeting Room and the Council Chamber of the Society at 41 Queen's Gate, London, S.W.7, and by the courtesy of the Imperial College of Science and Technology, the open meetings of the Conference were held in the Chemical Lecture Theatre of the Royal College of Science, Imperial Institute Road, London, S.W.7.

Opening of the Conference

The Conference assembled on the 7th July. The Chair was taken by Lt.-Col. J. G. Robertson, B.S.A., F.R.S.A., F.A.I.C., who welcomed the delegates in the following speech:—

I am very glad to welcome the delegates to this, the Sixth Commonwealth Entomological Conference. I had the pleasant duty of opening the Conference in 1948, when I was Chairman of the Executive Council of the Commonwealth Agricultural Bureaux, and I am speaking to you today on behalf of Mr. Morton, of the Union of South Africa, who now occupies that position. Mr. Morton wishes me to apologise for the fact that it has been impossible for him to be present today, and to extend to you his very best wishes for a successful Conference.

The Executive Council of the Commonwealth Agricultural Bureaux consists of one representative of the United Kingdom and one each from Canada, Australia, New Zealand, South Africa, India, Pakistan, Ceylon and Southern Rhodesia, together with a representative of the Colonial Territories. The Chairmanship of Council rotates at intervals of about two years.

The Commonwealth Agricultural Bureaux organisation is financed by contributions from the various Commonwealth governments in proportion to their interests. But all members of Council have equal voice in its affairs, although the Governments they represent do not contribute the same amounts financially.

The office of Secretary of the Executive Council is a very important post. Sir David Chadwick was the Secretary of the organisation from its inception until 1946, when he retired. To our great regret he died this spring, and I should like here to pay tribute to his efficiency and activity. Sir Herbert Howard, who is here today, has been our very capable and efficient Secretary since 1946, and he has been ably supported by Mr. Hay, as Assistant Secretary, and Mr. Churchill, who has been Acting Assistant Secretary since Mr. Hay's illness last year.

The Executive Council controls three Institutes and ten Bureaux. The three Institutes are the Commonwealth Institute of Entomology, of which you know a great deal and whose Director is Dr. W. J. Hall and Assistant Director Mr. E. O. Pearson; the Commonwealth Mycological Institute, under the Directorship of Dr. S. P. Wiltshire, assisted by Mr. Dade; and the Commonwealth Institute of Biological Control, which is situated in Ottawa, Canada, and whose Director, Dr. W. R. Thompson, we are very pleased to have with us today. I will not list the names of the various Bureaux or of their Directors and Consultant Directors, but they can be obtained from our Annual Report. Sufficient to say that they are all skilled in their work and efficient in the performance of their duties. At the present time there are ten of them, but the Council and the various Governments have under consideration the establishment of two or three more. Whether they will be established or not remains to be settled at the Commonwealth Agricultural Review Conference to be held next year.

The Executive Council controls the expenditure of a large amount of money which is contributed by the various Governments, totalling, in round figures, £143,000 to the ten Bureaux and £85,000 to the three Institutes or over £228,000 in all, which is no mean sum. These were the figures agreed by the 1950 Review Conference and represented a substantial increase on those for the preceding quinquennium, but costs generally are increasing and salaries have to go up with the increased cost of living. I do not think there is any scientific body that could not use more money, but we are treated very well by the various Governments of the Commonwealth and we for our part are reasonable in our requests.

The Conference starting today has to do with the Commonwealth Institute of Entomology. The history of the Commonwealth Institute of Entomology is comparatively long, that is, in comparison with the other bodies of the Commonwealth Agricultural Bureaux. It was founded in 1913 and is the senior of the Institutes and Bureaux. Its first Director was Sir Guy Marshall, who was in charge for a period of 29 years, from 1913 to 1942. The second Director was Dr. Sheffield Neave, who was Assistant Director for 28 years and Director from 1942 to 1946. The present Director, Dr. W. J. Hall, has been in office since 1946, and we hope it will be many years before he retires. I can bear tribute to the very great efficiency of all of these Directors, Sir Guy Marshall, Dr. Neave and Dr. Hall, and I think their work must agree with them because they are all happily still with us.

The Conference for which we are assembled today has been convened by the Executive Council and organised by the Commonwealth Institute of Entomology. There are 55 delegates. They are assembled from all over the Commonwealth, 14 from the United Kingdom, 11 from the self-governing Commonwealth countries, and 28 representing the Colonial territories, as well as a representative from Ireland and one from the Food and Agriculture Organization of the United Nations. It is most interesting to see from the printed programme the long list of oversea territories represented here today, and I think it may be said that we have a very good attendance from the Commonwealth as a whole.

The Fourth Conference, the last before the recent great war, was held in 1935. It was intended to hold these Conferences at five yearly intervals, but in 1940 and 1945 we were very busy with other matters, such as the Second World War, and, as a result, the Fifth Entomological Conference was not held until 1948. It was thought possible that we would hold the Sixth Conference in 1953, but for various reasons it was postponed until this year. Personally, I do not believe in too-frequent Conferences, but I consider that once in five or six years is most desirable. I hope that you will recommend another at a somewhat similar interval.

There are several objects in holding these Conferences, two perhaps more important than others. The first is the discussion of subjects which are of general interest and importance to entomologists or which have a special significance in some part of the Commonwealth, and the second is the discussion of the services of the Commonwealth Institute of Entomology. In regard to the first, there is a full programme of open meetings, consisting of 14 sessions, each devoted to a particular subject. The opening speakers at these sessions are for the most part people who have been working in these fields in this country, but particular interest will attach to the contributions of oversea delegates to the discussions that will follow. In regard to the second object, delegates will have the opportunity of giving, in delegates' sessions and in committee, their opinion on measures taken as a result of the last Conference. Your attention is also drawn to the fact that, for the first time, the reviews of work in the Commonwealth countries presented to the Conference are being printed. There are, in addition to other matters of particular interest to the Commonwealth Institute of Entomology, certain subjects of general interest to be discussed in open session on which delegates' views may be sought in committee.

I do not know whether Dr. Hall is going to touch upon the increased accommodation which we hope to have for the Institute, but I will mention the subject briefly and he can elaborate on it. The present accommodation in 41 Queen's Gate, where we are at the moment, is too restricted. After a prolonged search in the immediate vicinity, Dr. Hall has found suitable premises close at hand, of which, it is hoped, a 44½ year lease may be secured. I think it is desirable to obtain a long lease, if possible, and I hope that the Institute will shortly have very much improved accommodation.

The finances of the Institute will be gone into when the Review Conference meets next year. It is sufficient to say that the present contributions from the Governments to the Institute of Entomology amount in round figures to £34,000. The sale of publications is a substantial amount, £10,000, and the balance from last year of £11,000, with other receipts, brought the total for the year ending 31st March, 1954 up to roughly £58,000.

The Executive Council will study the report of this Conference with great interest and you may rest assured that such recommendations as you may put forward will receive the most serious consideration.

It is therefore with high confidence in you, Gentlemen, and extending to you a very hearty welcome, that I declare the Sixth Commonwealth Entomological Conference now open.

Formation of Committees

The opening of the Conference was followed by a session at which the Director of the Commonwealth Institute of Entomology discussed the Memorandum (Appendix I) on the work of the Institute during the past six years and the action taken on the resolutions submitted to the Executive Council of the Commonwealth Agricultural Bureaux by the last Conference.

Dr. Hall also mentioned the arrangement entered into with the Colonial Office by which the Institute, on behalf of the World Reporting Service of the United Nations Food and Agriculture Organization, collates information on outbreaks of insect pests sent in by the Colonial territories and transmits it for publication in their Plant Protection Bulletin. Dr. Hall reminded delegates that two types of information were desired, (i) notification of the appearance of a pest new to the country, (ii) a half-yearly report on any major developments as regards insect pests. The notifications were transmitted immediately to the Food and Agriculture Organization; the reports were combined by the Institute into single reports by continental regions. The number of half-yearly reports received so far had been disappointing: it was emphasised that only a concise note was required. Dr. Logothetis appealed for support for the Plant Protection Bulletin, asked for suggestions for improving it, and stressed the importance of reducing the time-lag between the discovery and public notification of outbreaks.

After discussion, a General Committee was appointed to give detailed consideration to the activities of the Commonwealth Institute of Entomology, and to any other matters that might be raised by delegates or in the open meetings of the Conference. It was also agreed, following a suggestion by Dr. W. R. Thompson, that the General Committee should consider the affairs of the Commonwealth Institute of Biological Control, and that it should have powers to co-opt additional members for this purpose. A Memorandum (Appendix II) on the History and Work of the Commonwealth Institute of Biological Control by the Director, Dr. W. R. Thompson, was accordingly distributed to members of the Committee. Copies of a Memorandum on Central African Resources for Biological Control, that had been prepared for discussion by Dr. R. H. Le Pelley, were distributed to all delegates.

The General Committee was composed as follows:—

Dr. I. Thomas (Chairman)	United Kingdom.
Mr. D. V. W. Abeygunawardena	Ceylon.
Dr. Taskhir Ahmad	Pakistan.
Mr. A. B. Baird	Canada.
Dr. J. Carroll	Ireland.
Mr. I. F. B. Common	Australia.
Mr. B. B. Given	New Zealand.
Prof. T. W. Kirkpatrick	Trinidad.
Dr. R. H. Le Pelley	Kenya.
Dr. E. S. Narayanan	India.
Prof. O. W. Richards	Colonial Office Delegation.
Mr. J. A. Whellan	Southern Rhodesia.

Dr. W. J. Hall, Mr. E. O. Pearson and Capt. H. S. Bushell, all of the Commonwealth Institute of Entomology, attended all the meetings of the Committee, but were not members of it. Similarly, Dr. W. R. Thompson attended the meetings of the Committee at which the affairs of the Commonwealth Institute of Biological Control were discussed, and on the first of these occasions Mr. H. C. James (Jamaica), Dr. R. Mamet (Mauritius), Dr. T. H. C. Taylor (Colonial Office Delegation), Mr. R. W. E. Tucker (Barbados) and Dr. J. M. Waterston (Nigeria) were present by invitation.

A report of the work of the General Committee is given in Appendix III A. It submitted its recommendations at the closing plenary session of the Conference, at which they were in some cases slightly amended and then adopted as resolutions of the Conference.

Papers and Discussions

The papers read at the open meetings of the Conference, together with a summary of the discussions that followed, are printed as Appendix IV to this report.

Official Reception and Supper

Her Majesty's Government in the United Kingdom entertained the delegates to the Commonwealth Entomological and Mycological Conferences to supper, held by the gracious permission of Her Majesty the Queen at Hampton Court Palace on 15th July. The Minister of Agriculture and Fisheries, the Right Honourable Sir Thomas Dugdale, Bt., T.D., M.P., presided and proposed the toast of " The Entomological and Mycological Conferences ". The Acting Vice-Chairman of the Executive Council, Lt.-Col. J. G. Robertson, replied on behalf of the Commonwealth Agricultural Bureaux, and Dr. E. S. Narayanan replied on behalf of the delegates to the Entomological Conference and Dr. C. J. Magee on behalf of the delegates to the Mycological Conference.

Visits, etc.

Visits were made to Rothamsted Experimental Station, the Field Station of the Imperial College of Science and Technology at Silwood Park, Sunninghill, and the Pest Infestation Laboratory of the Department of Scientific and Industrial Research, at Slough. Receptions for the delegates were given by the Trustees and Director of the British Museum (Natural History), and by the President and Council of the Royal Entomological Society of London.

Proceedings at the Final Meeting

At the final meeting of the Conference on 16th July, the chair was taken by Lt.-Col. J. G. Robertson, Acting Chairman of the Executive Council of the Commonwealth Agricultural Bureaux.

After the resolutions recorded below had been adopted, a vote of thanks was passed, on the motion of Dr. R. H. Le Pelley, seconded by Professor V. B. Wigglesworth, on behalf of the delegates, to the Executive Council of the Commonwealth Agricultural Bureaux for convening the Conference, and to the Director and staff of the Commonwealth Institute of Entomology for the successful manner in which the Conference had been conducted.

The Director thanked the delegates on behalf of the staff of the Institute, and the Chairman, in bringing the Conference to a conclusion, added his thanks and expressed his personal satisfaction with the course the Conference had taken.

Conclusions and Resolutions

1. The Conference desires to record its appreciation of the services rendered by the Commonwealth Institute of Entomology and the Commonwealth Institute of Biological Control to scientific workers in the Commonwealth, and to express the hope that at the Commonwealth Agricultural Bureaux Conference to be held in June 1955 adequate financial provision will be made to enable the services of these Institutes to be maintained, and where necessary extended, for a further period of five years.

2. The Conference has noted with satisfaction that the steps taken by the Executive Council of the Commonwealth Agricultural Bureaux in respect of the conclusions and resolutions adopted by the Fifth Commonwealth Entomological Conference in 1948 have resulted in effective action being taken in the majority of instances.

3. The Conference appreciates the careful consideration given by the General Committee and the Committee on Taxonomy to the matters brought before them and makes the following resolutions (4–25) based on the recommendations put forward by those Committees.

Services of the Commonwealth Institute of Entomology

4. The policy of selection of material for abstract that the *Review of Applied Entomology* has been compelled to adopt as a result of the increasing volume of publications in economic entomology is approved.

5. The reduction in the time between the receipt and the publication of papers accepted for the *Bulletin of Entomological Research* that has resulted from its increase in size is noted with approval and the recommendations of the 1948 Conference regarding size and content of *Bulletin* papers are supported and emphasised.

6. The information given in the *Distribution Maps of Insect Pests* should continue to be based on published records and on material currently regarded as authentic in the collections of the British Museum (Natural History) and records of the Commonwealth Institute of Entomology, and appreciation is recorded of the usefulness of these maps. They must, of course, be used with reasonable discretion in connection with quarantine matters.

7. The Identification Service of the Institute urgently requires strengthening by the appointment of three further specialists, one of whom should work on the Acarina.

8. The proposals made at the 1948 Conference regarding periodic statements on the nature of research in progress in all Commonwealth countries have met with a lack of response and should be simplified. The Institute should therefore, at yearly intervals, ask each Commonwealth country to furnish a list of current research projects in economic entomology, with their location and the names of those in charge, so that this information can be provided by the Institute on request.

Services of the Commonwealth Institute of Biological Control

9. The proposals for the establishment of substations of the Institute in India and Pakistan are approved.

10. A substation of the Institute should also be established in East Africa, both to make available to the Commonwealth territories in Africa and elsewhere the parasite resources of this area, and to study the basic principles of biological control, with particular reference to problems of the control of tropical pests.

11. The establishment of a substation in India and one in Pakistan will make it ultimately necessary to take on to the strength of the Institute the four entomologists who will staff these substations.

12. The establishment of a substation in East Africa will necessitate the appointment of two entomologists.

13. The need to link basic research with specific parasite projects is emphasised, and requires the appointment of three additional entomologists, one at each of the three substations that now exist in California, Trinidad and Switzerland.

The Supply and Training of Taxonomists

14. The Memorandum on the Commonwealth resources for the identification of insects of economic importance (Appendix V A), submitted by the Commonwealth Institute of Entomology to the Standing Committee of the British Commonwealth Scientific Conference, provides an analysis of the situation with which the Conference is in agreement.

15. The existing provisions for taxonomic research and for identification services are quite inadequate, the work of the economic entomologists is, in consequence, being seriously hampered, and steps must be taken to rectify this situation.

16. The identification of insects of economic importance is dependent on the state of taxonomic research, and identification services cannot, therefore, be improved unless taxonomic research is increased.

17. An important factor militating against the recruitment of potential first class taxonomists is the relatively small number of posts available in the Commonwealth, and a substantial increase in this number would attract talent that is at present deflected elsewhere. It is considered that, in some instances, conditions of service, and prospects, need improvement.

18. It is therefore strongly recommended that:

(*a*) the volume of taxonomic research should be increased by an early and substantial expansion of staff in the organisations in the Commonwealth engaged in this work, particularly in the British Museum (Natural History), which is a key institution, and also in other appropriate museums and Departments of Agriculture or of Scientific Research in the Commonwealth countries;

(*b*) special consideration should be given to the fact that the output of basic taxonomic research would also be greatly increased by making additional supporting staff and ancillary services available to taxonomic research workers.

19. Much could be done throughout the Commonwealth to improve the quality of taxonomic research and to attract first class workers by:

(*a*) bringing to the notice of Universities and other Research Institutes (apart from Museums) the importance of taxonomic problems that can be solved only by experimental work;

(*b*) offering more post-graduate studentships for work on appropriate taxonomic problems;

(*c*) facilitating interchange of workers between different countries of the Commonwealth;

(*d*) appointing teams to study special problems, as exemplified by the existing Colonial Termite Research Unit and the Loiasis Research Team;

(*e*) providing taxonomists with more opportunities for field investigation of problems with which their work is concerned;

(*f*) providing funds from which grants could be made for the speedy publication of the results of taxonomic research in groups of major importance.

20. The foregoing resolutions should be brought to the notice of the Standing Committee of the British Commonwealth Scientific Conference, the Ministry of Agriculture and Fisheries (England and Wales), Ministry of Agriculture (Northern Ireland) and Department of Agriculture (Scotland), the Colonial Office, the Trustees of the British Museum (Natural History), the Agricultural Research Council, the Nature Conservancy, the Department of Scientific and Industrial Research, the Medical Research Council, and the University Grants Committee and, after consultation with the respective Scientific Liaison Officers, the bodies most concerned in Commonwealth countries.

Termite Research

21. The establishment by the Colonial Office of the Unit for research on the biology and taxonomy of termites, which implements the recommendation of the 1948 Conference, is warmly welcomed. While the Unit, as at present constituted, very properly does not engage in advisory or control work, the appointment of an officer to the Unit specifically to investigate methods of control of termites as pests in agriculture and forestry is strongly recommended.

Research on Pests of Stored Products in the Tropics

22. In view of the increasing importance of the storage of foodstuffs and other products in the tropical territories of the Commonwealth, and the fact that this involves many basic problems that can be investigated only under tropical conditions, provision for such work under appropriate guidance at a suitable research station in a tropical territory should be made.

Research on Pests of Tropical Cereal Crops

23. In view of the great reduction in food production in the tropics caused by the insects that attack tropical cereal crops, especially stalk borers and midges, immediate action should be taken to set up a Research Team to study these pests in all their aspects.

Reviews of Work

24. The decision to publish the reviews of work in economic entomology in the various Commonwealth countries for the period 1948-1954 is endorsed. Similar reports should be prepared for the next Conference and, to this end, a memorandum embodying suggestions for further improvements should in due course be circulated by the Commonwealth Institute of Entomology to the chief entomologists of the various Commonwealth countries.

Plant Quarantine Station at Kew Gardens

25. The special greenhouse that has been maintained at Kew since 1951 for holding in quarantine planting material in transit between Commonwealth countries provides a useful service that should be continued.

Accommodation of the Commonwealth Institute of Entomology

26. The Conference learns with satisfaction that enlarged accommodation for the Institute may shortly be secured. It considers that it is of vital importance, for the services rendered by the Institute to economic entomology throughout the Commonwealth, that such accommodation should be both adequate and as close as possible to the present site.

Acknowledgements

27. The Conference wishes to tender its grateful thanks to Her Majesty's Government in the United Kingdom, the Trustees of the Natural History Museum, and the Royal Entomological Society of London for the hospitality extended to it, and to the last named also for the privilege of using its Council and Meeting Rooms. It also wishes to thank the Imperial College of Science and Technology for the use of one of its large lecture theatres for the open meetings.

28. The Conference wishes that its grateful thanks be conveyed to Sir William Ogg, Professor O. W. Richards and Mr. G. V. B. Herford, O.B.E., and their staffs, for the welcome accorded to the delegates on the occasion of their visits to Rothamsted Experimental Station, the Imperial College Field Station, and the Pest Infestation Laboratory, and for the admirable arrangements for the display and explanation of the work in progress at these centres.

Future Commonwealth Entomological Conferences

29. The Conference re-affirms the value of periodical meetings of entomologists drawn from as many countries of the Commonwealth as possible and recommends that steps be taken in due course for a Seventh Commonwealth Entomological Conference to be held in 1959, of which long notice should be given to enable the necessary arrangements to be made, at a place to be decided by the Executive Council of the Commonwealth Agricultural Bureaux.

APPENDIX I

MEMORANDUM ON THE WORK OF THE

COMMONWEALTH INSTITUTE OF ENTOMOLOGY

FROM 1ST APRIL, 1948 TO 31ST MARCH, 1954

It will be appropriate to begin this memorandum by recording the steps taken to implement a number of the resolutions submitted to the Executive Council of the Commonwealth Agricultural Bureaux by the last Conference. These are dealt with below, the numbers being those attached to the resolutions on pp. 9-13 of the Report of the 5th Commonwealth Entomological Conference, 1948.

Size of the *Bulletin of Entomological Research* (3a)

The size of the *Bulletin* was increased as from the beginning of 1950 (Vol. 41), and at the same time the subscription rate was raised from £2 to £3 per volume. Since 1950 it has ranged in size (exclusive of indexes) from 734 to 810 pages.

Increased staff for the Identification Service (8)

The Commonwealth Agricultural Bureaux Review Conference 1950 sanctioned two new posts and these were filled by the appointment of Dr. D. J. Williams (Coccidae) in December 1952 and Mr. R. D. Eady (Parasitic Hymenoptera) in January 1954.

Revisionary work on insects of economic importance (10)

Since the 1948 Conference some 105 technical publications totalling 2,600 pages have been published by members of the staff. These include a considerable amount of revisionary work and in several cases include keys. Major revisions under way include those of the genus *Apanteles* in the Braconidae, the genus *Schizonycha* in the Melolonthidae and the Muscidae of the Indian Region. A revision of the Ethiopian Pseudococcidae, in collaboration with Mr. de Lotto of the Kenya Department of Agriculture, is also planned. Keys in the course of preparation include one to the larvae of British Chrysomelidae and one to the immature forms of African Cerambycidae. A revision of the African species of *Sesamia* and related genera of stalk borers by Mr. W. H. T. Tams of the British Museum (Natural History) and Mr. J. Bowden of the Department of Agriculture, Gold Coast, was suggested and encouraged by the Institute.

Distribution Maps of Insect Pests (11)

The first maps were produced in 1951 and a total of 36 has now been issued, six in June and six in December of each year.

Statements on research in progress in Commonwealth countries (12)

With two exceptions no statements on the lines suggested have been received.

Accommodation of the Commonwealth Institute of Entomology (13)

Negotiations are in progress for the acquisition of a 44½ year lease in Queen's Gate for that part of the Institute at present housed in 41 Queen's Gate. Instead of the three floors and part of the basement which we occupy at present we should then have a whole house of almost exactly similar design, which would satisfy our accommodation requirements for many years to come. It would give us the extra space for the library and personnel, including visitors, of which we have been sorely in need for so long.

Biological control (14)

A committee consisting of seven delegates was set up at the last Conference and produced a memorandum that was submitted to the Commonwealth Agricultural Bureaux Review Conference, 1950. That Conference considered the memorandum but recommended that the Bureau of Biological Control should continue to be located in Canada and authorised the Executive Council to increase the number of field stations as might be desirable and so far as financial provisions might permit (Report of Proceedings, 1951, paras. 114-117).

Research on termites (16)

This recommendation was brought to the notice of the Committee for Colonial Agricultural, Animal Health and Forestry Research. As a result a Colonial Termite Research Unit was formed under a scheme financed by Colonial Development and Welfare Funds. Mr. W. V. Harris was appointed Officer-in-Charge and there are now in addition three other entomologists employed under the scheme.

Manual on protection from termites (17)

A manual entitled " The Protection of Buildings and Timber against Termites " was prepared by Mr. W. D. MacGregor, C.B.E., B.Sc. and published in 1950 by the Department of Scientific and Industrial Research as Forest Products Research Bulletin No. 24.

Nomenclature of insecticidal chemicals (19-23)

In considering these resolutions the Executive Council was in some doubt whether such a subject would not be more appropriately handled by the British Standards Institution. A technical Committee was subsequently set up in 1949 under the aegis of the Institution with Mr. H. Jones as Chairman. A considerable number of meetings have been held and two lists of Recommended Common Names for Pest Control Products have been issued as British Standard 1831 : Parts 1 and 2. The Director is a member of this Committee.

African continental quarantine (24-27)

Immediately following the Conference in 1948, a Phyto-Sanitary Conference was convened by the Colonial Office. This Conference drew up a draft of a Phyto-Sanitary Convention for Africa south of the Sahara. Although general agreement was reached by the delegates, the Convention has still not been ratified by Governments.*

It is satisfactory to note that the Review Conference, 1950, placed on record its view that the *Bulletin of Entomological Research* was one of the most valuable activities of the Institute and also approved the collaboration of the Institute with the Colonial Office in the establishment of a pool of entomologists for the study of specific problems in the Colonial Empire. It also welcomed the fact that the Institute was to act as a centre of information in connection with the Phyto-Sanitary Conventions proposed for Africa and South East Asia (Report of Proceedings, p. 19).

It is worthy of note that in the financial year 1951-52 our total receipts from the sale of publications exceeded £10,000 for the first time in the Institute's history, and in the year 1953-54 reached a new record at £10,210. As the entire distribution of our publications and the collection of all moneys are dealt with at 41 Queen's Gate it will be realised that this is an activity of no mean magnitude. Further evidence of the growth of the Institute's work will be apparent from the details given below.

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* See footnote, p. 28.

Publications

Review of Applied Entomology

This monthly publication is now in its 42nd volume and continues to be probably the Institute's most important publication.

Attention was drawn in the Memorandum submitted to the Fifth Commonwealth Entomological Conference in 1948 to the tendency for the literature to become more difficult from an abstracting point of view and that consequently the time required per abstract had tended to become longer. This is still more the case today. The position is further complicated by the growing volume of literature. For many years past a policy of selection has been adopted and this has had to be made more stringent. Every endeavour is made, however, to abstract all those papers which contain important new information so that the *Review* shall continue to be a work of reference of prime importance to all economic entomologists.

The number of subscribers to Series " A " and Series " B " and the total cash receipts from this source over the past six years with corresponding figures for 1947 for comparison are shown below.

			No. of Subscribers " A "	" B "	*Total Cash Receipts* £	s.	d.
Vol.	35.	1947	860	739	3,225	8	5
„	36.	1948	924	787	3,253	15	5
„	37.	1949	949	803	4,146	7	8
„	38.	1950	1,042	865	4,579	4	3
„	39.	1951	1,131	935	5,335	8	3
„	40.	1952	1,198	967	4,631	16	11
„	41.	1953	1,232	1,025	5,197	9	8

It will be seen that the number of subscribers to Series " A " has increased from 860 to 1,232 and to Series " B " from 739 to 1,025. For the first time the number of subscribers to Series " B " has passed the 1,000 mark.

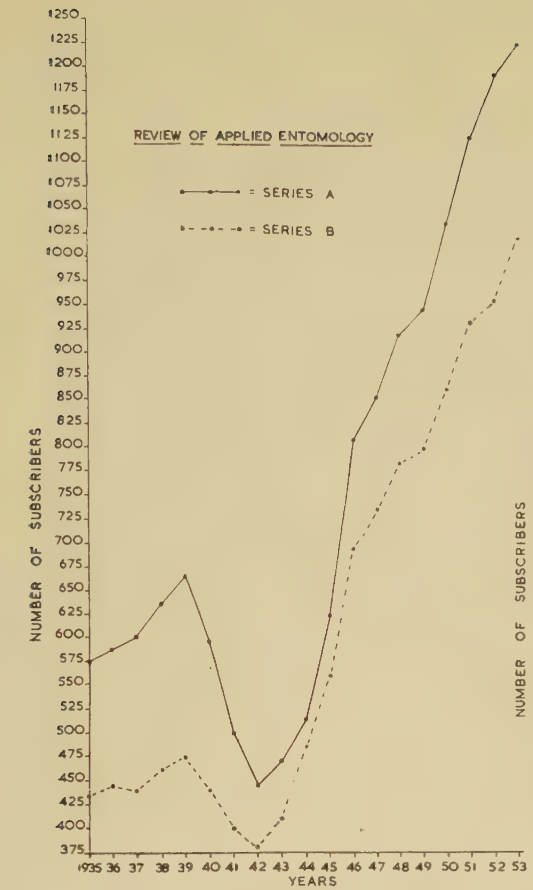
The total cash receipts include the sale of back volumes, the demand for which remains at a satisfactory high level. It is hoped that this demand will continue. Any tendency to fall away should be offset, to some extent, if the present rate of increase in the number of subscribers can be maintained and by the fact that each year that passes adds another to the now considerable number of back volumes.

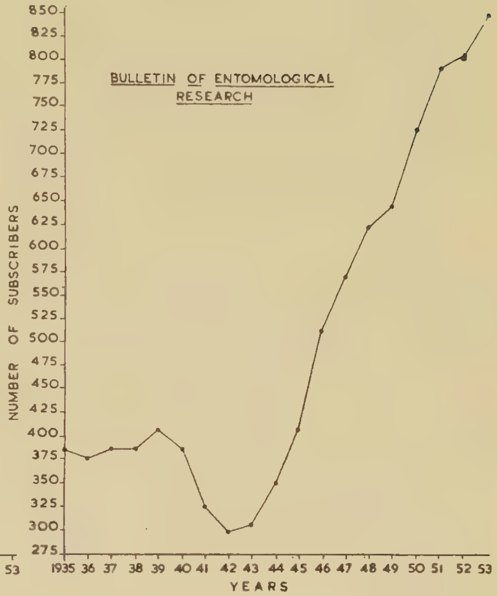
A new edition of the list *Serial Publications Examined* was prepared and issued to all recipients of the *Review of Applied Entomology* in November 1953. This list gives details of the journals and of their countries of origin, received currently in the Library. It replaces the first edition which was published in 1948 and its supplement issued in 1950.

Bulletin of Entomological Research

This quarterly journal has appeared regularly and is now in its 45th volume. For the first time since 1943 the four parts of the annual volume appeared within the year, the Part 4 of the 1953 volume being distributed at the end of December. Now that we are up to date, it is hoped that all parts will appear in future at the correct interval.

The increase in size recommended by the 1948 Conference has reduced the delay in publication to a year or slightly less. The number of manuscripts received maintains a high level.





The size of the volumes during the past six years is shown below.

	Year	*No. of Pages (exclusive of Index)*	*No. of Plates*	*No. of Articles*
Vol. 39.	1948	575	24	36
„ 40.	1949	558	9	40
„ 41.	1950	778	21	48
„ 42.	1951	784	24	62
„ 43.	1952	734	25	48
„ 44.	1953	810	16	58

The number of subscribers and the total cash received in respect of the *Bulletin* are tabulated below.

		No. of Subscribers	*Total Cash Receipts* £	s.	d.
Vol. 38.	1947	572	1,674	6	5
„ 39.	1948	623	1,751	15	8
„ 40.	1949	645	2,250	11	4
„ 41.	1950	728	3,327	9	9
„ 42.	1951	792	3,692	1	5
„ 43.	1952	808	3,639	19	0
„ 44.	1953	848	3,902	14	3

As will be seen from the above figures, the number of subscribers has shown a satisfactory advance. The increase in the subscription from £2 to £3 commencing with the 1950 volume does not appear to have affected the number of subscribers.

The considerable increase in the figures for total cash receipts is due in large measure to the increased subscription rate. The sale of back volumes has also been maintained and represents a substantial amount in the total cash receipts for each year. As in the case of the *Review*, the same remarks concerning the future prospects for the sale of back numbers apply equally here.

Zoological Record

The *Insecta* part of this work, published by the Zoological Society of London, has been prepared annually by the Institute. The contribution towards the cost of preparation was increased by the Society in 1948 from £100 to £175 and, in addition, the Institute receives the major portion of the proceeds of the sale of the separate part amounting to £501 in 1953.

For very many years Miss R. M. Davenport prepared the *Insecta* and many entomologists throughout the Commonwealth will learn with regret that she was obliged to resign in September 1953 on account of ill-health, after 32 years' service with the Institute. It is impossible, of course, to replace her wide knowledge and experience but her understudy, Miss H. B. White, is settling down well to the task of preparing this work.

Distribution Maps of Insect Pests

In compliance with the wishes of the last Commonwealth Entomological Conference and the Review Conference 1950, the first maps were produced in 1951 and have been issued at the rate of 12 per annum. Despite the fact that these maps have been very well received, the number of subscribers in 1953–54 was only 264. It is hoped that there will be an improvement in this disappointing figure as the maps become more widely known.

Sundry Publications

Seven works have been separately published during the period under review as follows:

List of Recorded Cotton Insects of the World, by H. Hargreaves, in September 1948.
Report of the Fifth Commonwealth Entomological Conference, 22nd–30th July, 1948, in December 1948.
Air Transport and Insects of Agricultural Importance, by W. A. L. David, in July 1949.
A Synopsis of the World Literature on the Fruit Tree Red Spider Mite *Metatetranychus ulmi* (C. L. Koch, 1935) and its predators, by Joan R. Groves, in March 1951.
The Association of Ants with Aphids and Coccids, by G. E. J. Nixon, in March 1951.
The Injurious Insects of the British Commonwealth, by J. W. Evans, in April 1952.
List of Sugar-cane Insects, by H. E. Box, in June 1953.

Reference has already been made to the fact that many taxonomic papers have been published by members of the staff in various scientific journals. The figures for the past six years are as follows:

	No. of Papers	*No. of Pages*	*No. of Staff concerned*
1948	17	235	6
1949	19	195	6
1950	21	807	7
1951	15	162	4
1952	13	503	6
1953	32	859	9

In addition to the above, we have arranged for the publication of a number of papers by taxonomists who have described new species from material submitted to them by the Institute.

The Library

During the past six years, the average annual growth of the library has been 238 (253) bound volumes, 1,239 (931) pamphlets and 626 (473) periodical publications, the figures in brackets being the annual average for the previous seven years. Works issued on loan amounted to 1,633 (880) annually.

The library now contains some 13,260 bound volumes and 41,068 pamphlets. The author catalogue of monographs and separates is up to date and 72·4 per cent. of the entomological contents of the volumes of periodicals in the library have been catalogued. The sheaf catalogue of serial and official publications is up-to-date as is the subject index to monographs.

The much increased volume of literature that is coming into the library involves considerable extra work and strain on existing space. The number of loans sent out during the financial year 1953–54 reached a new peak of 1,939, providing further evidence of the increase in this branch of the Institute's activities.

Daily use was made of the library by staff and visitors both from this country and overseas but the lack of sufficient accommodation for visitors who wish to work in the library is a serious handicap. Owing to the acute shortage of space, it became necessary in 1950 to remove some of the works in the library, least in demand, to the vicinity of Horsham where suitable accommodation had been found. Although this has eased the pressure at Queen's Gate it has proved most inconvenient. If the present negotiations for new premises are successfully concluded, it will be possible to have the whole library under one roof again and there will be adequate space for visitors who wish to work in it.

The demand by entomologists overseas for microfilms or photocopies of articles or extracts from articles is increasing and, during the year 1953–54, 82 were supplied against payment on behalf of 8 Commonwealth and 4 foreign countries.

Surplus publications have been distributed to the other Bureaux and to libraries in the Commonwealth either through the British National Book Centre and UNESCO or direct. In return the library has received gifts partly in exchange from various individuals and institutions.

Identification of Insects

The importance of this aspect of the Institute's activities was stressed at the 1948 Conference, and the 1950 Review Conference recognised it by authorising the appointment of two further specialists. These appointments have since been made.

The need for more taxonomists is becoming more widely recognised and gave rise to a resolution at the British Commonwealth Scientific Conference, Australia, 1952. It is felt that the matter is of such importance that it has been placed on the Agenda for discussion during the present Conference.

The number of identifications sent out by the Institute in the past six years is given in the following Table.

Year	Africa	America	Asia	Australia, New Zealand and Pacific Is.	Europe	Total
1948–49	3,936	671	476	556	741	6,380
1949–50	2,873	490	1,071	330	744	5,508
1950–51	3,215	300	1,223	433	632	5,803
1951–52	3,545	158	1,710	396	644	6,453
1952–53	4,927	224	2,000	469	828	8,448
1953–54	3,515	122	2,881	654	569	7,741

A notable and pleasing feature of the past few years has been the increase in the amount of material received and identified on behalf of India and Pakistan. During the late war and immediately after partition, the number of collections received from this region, and consequently the number of identifications made, greatly decreased and reached a minimum in 1948–49, when only 61 identifications, or barely one per cent. of the Institute's total were made for these two countries. Since then the amount of material received has risen rapidly, and in 1953–54 reached pre-war levels, 55 consignments containing over 4,500 specimens being received from India and Pakistan together, compared with 54 consignments containing 5,700 in 1938–39. The number of identifications sent back was 1,091, representing over 14 per cent. of all those made by the Institute during the year. This substantially exceeds the pre-war totals for this region, the highest of which was 873 in 1931–32, and it appears that the amount of work being carried out for both India and Pakistan at the present time is probably greater, both absolutely and as a proportion of the Institute's total, than at any previous time in our history.

Eight members of the staff are engaged on full-time identification work whilst two others devote only a part of their time to such work. Since the last Conference the Institute has lost the services of four very valuable members of its staff. Mr. D. J. Atkinson, O.B.E., died suddenly in March 1952, Dr. J. W. Evans resigned in October 1948 and Dr. A. P. Kapur returned to India in March 1949 at the end of his period of secondment. Dr. T. H. C. Taylor, who devoted part of his time to such work, was released in April 1953 to take up an appointment with the Anti-Locust Research Centre.

Mr. N. C. E. Miller was appointed in 1949 to the vacancy caused by Dr. Evans' departure and Mr. E. A. J. Duffy in 1952 to replace Mr. D. J. Atkinson. Mr. Pope was appointed in 1949 to work on the Coleoptera and Dr. Williams and Mr. Eady in 1952 and 1954 to work on the Coccoidea and Parasitic Hymenoptera respectively.

The Institute is extremely fortunate in having the very valuable assistance, as part-time workers, of Sir Guy Marshall in dealing with the Curculionidae, of Mr. G. E. Bryant, with the Chrysomeloidea and of Mr. R. J. Collins with some sections of the Lepidoptera.

We are also fortunate in having available Mr. W. V. Harris, the officer-in-charge of the Colonial Termite Research Unit, attached to the Institute. We are thus now, for the first time for many years, able to obtain determinations of termite material sent in from overseas as there was previously no specialist on the group in this country. This satisfactory position is the direct result of one of the recommendations of the last Conference.

Mr. E. S. Brown, a member of the pool of entomologists, has been engaged on some very useful taxonomic work in the period intervening between two overseas assignments.

We continue to receive much valuable assistance from specialists on the staff of the British Museum (Natural History) in certain groups and it is a pleasure to record our warm appreciation of their friendly and ever ready co-operation. We must also acknowledge the willing co-operation of workers elsewhere in the United Kingdom, the Commonwealth and other countries who undertake identifications for us in special groups.

During the period 1948–54, a total of 95,386 specimens has been presented to the British Museum, including the types of 964 species and examples of 1,511 others not previously represented in the collections.

The Pool of Entomologists

Mr. E. S. Brown and Mr. C. R. Wallace joined the staff at the beginning of 1952. Mr. Brown proceeded almost immediately to the Seychelles to study the coconut pest, *Melittomma insulare* and its control. He returned in April 1953 on the conclusion of his investigation, a detailed description of which has been published in the *Bulletin of Entomological Research* for 1954 (part 1). He left for the Solomon Islands in April 1954 to study another coconut pest, this time *Amblypelta cocophaga*, which causes serious nutfall.

Mr. Wallace went to British Guiana in July 1952 to make a study of the padi bug, *Solubea poecila*. He returned in April 1954 on the conclusion of his investigation, the results of which are to be written up for publication in due course. On his way back from British Guiana, Mr. Wallace spent six weeks in Grenada, at Government request, to make a brief survey of the cacao beetle, *Steirastoma breve*. Towards the end of this year, he will be sent overseas on another investigation to be selected from the requests that have been received for the services of a member of the pool.

General Information

A very great deal could be written about the large number of enquiries for information that have been dealt with annually. They cover almost the entire field and often require considerable research. They include requests for advice on specific problems, research projects, references to published information on individual pests or classes of insects, information on taxonomic problems relating to insects of economic importance and to many other subjects of an entomological nature.

All members of the staff are involved to a greater or lesser degree on this extremely important aspect of the Institute's activities and much time is devoted to this very worth-while work.

Staff Changes

In addition to the staff changes referred to under " Identification of Insects " and " Publications—Zoological Record ", Mr. E. O. Pearson, B.A., formerly of the Empire Cotton Growing Corporation, was appointed Assistant Director and took up his duties on 1st April, 1953. Mr. W. Ruttledge, M.A., formerly of the Entomological Section of the Research Division of the Department of Agriculture and Forests, Sudan Government, joined the staff in 1950 for bibliographical duties.

The Institute has suffered the loss of two Preparators, Mr. L. B. Wyatt and Mr. F. Alford in 1952 and 1951 respectively. Mr. Wyatt had the maximum possible length of service with the Institute, being one of the original members of the staff in 1913. His skill and experience as a preparator, and his knowledge of the Institute's early history were of the greatest value. Mr. Alford died from the effects of a war-time disability; he joined the staff in 1946 and had proved himself a most useful member of the staff.

In conclusion, I must place on record my deep appreciation of the services of the staff who have supported me throughout in a wholehearted and loyal manner.

APPENDIX II

MEMORANDUM ON THE HISTORY AND WORK OF THE COMMONWEALTH INSTITUTE OF BIOLOGICAL CONTROL

During the interval of almost twenty years that has elapsed since the last Commonwealth Entomological Conference that the Director of the Commonwealth Institute of Biological Control has been able to attend, many changes have occurred in the personnel of entomological departments throughout the Commonwealth and there may be many delegates at this Conference who are not very fully informed about the organisation. It has seemed desirable, therefore, to give a brief account of the recent history of the service, the objectives envisaged and the progress made towards realising them, and the defects that must be remedied to enable it to render the service to the Commonwealth it is capable of giving. The brief historical sketch presented by Sir Herbert Howard at the 1948 Entomological Conference will serve as a background for the present more technical account.

About 1925 the Imperial Institute of Entomology began to receive from some of the Dominions enquiries about the collection of beneficial insects for use against certain imported pests and it seemed that the creation of a permanent and central laboratory for work of this kind would be advantageous to the Commonwealth in general. This was effected by means of grants from the Empire Marketing Board which enabled the Institute of Entomology to purchase and equip a laboratory at Farnham Royal.

Active work began there in 1928 on a number of projects of interest to the Dominions as soon as a competent staff could be assembled. The facilities for work at Farnham Royal were excellent up to a point but, apart from a number of very serious financial difficulties and uncertainties, there was a grave defect which was not clearly apparent during the first years of the work but soon came into view, and this was the location of the laboratory in the United Kingdom. Owing to the peculiar climate of Great Britain and the restricted character of its fauna and flora, its potentialities as a centre for the collection of material for the British Commonwealth are extremely limited. During the early years of the work the limited staff was fully occupied in work for countries in the temperate zone and particularly for Canada, New Zealand and Australia. The Parasite Laboratory could not, however, from the regions immediately available to it, supply material for tropical and sub-tropical areas. An effort was made to correct this position by the assignment of an officer to the West Indies and the establishment of a small laboratory in the Mediterranean area, but these ventures had later to be wound up for lack of funds.

After the transfer in 1933 of the Institute of Entomology to the Executive Council of the Imperial Agricultural Bureaux, the future of the Parasite Laboratory remained uncertain, and continued financial support from the Council was not very easily obtained. One reason for this was that the laboratory was unable to do much for several of the countries represented on the Council. It had, for example, done very little for India, for South Africa, for the Colonial Empire and, save in exceptional circumstances, for Great Britain, for the very reason that it was located in Great Britain. Eventually, however, it was agreed to recommend to governments the continued service of the parasite service to the extent of the annual income which it had originally received from the Empire Marketing Board. The proviso was added that, in order to establish some relation between the use made of the service and the contributions to its upkeep, part of its maintenance must come from fees collected for projects. When, however, war broke out in 1939 and the continent of Europe was closed to our work, it became evident that with the difficulty of obtaining and filling orders from its clients and with its deficitary budget the organisation could not carry on at Farnham Royal. The Council was therefore obliged to give almost all members of the staff their statutory notices of termination of appointment. In August 1940 the Director was transferred to Canada, where the Canadian Government generously provided temporary quarters in the Parasite Laboratory in Belleville. Other members of the staff followed, Dr. D. C. Lloyd arriving towards the end of 1940 and Mr. F. J. Simmonds in 1941. Reduced again to very small beginnings, it was necessary to start rebuilding the work. Farnham House was let and thus provided a small revenue, and quarters and services at the Belleville laboratory were provided free, so that the cost of operations was reduced to a very low level.

Early in 1941, Dr. Lloyd was transferred to the Citrus Experiment Station in Riverside, California, where he was given free quarters by the Division of Biological Control and began work on the codling moth parasites in that area. In the autumn of 1942, Dr. Lloyd was moved to South America where he opened a sub-station in Montevideo, Uruguay, for work on behalf of Canada on the parasites of locusts and grasshoppers. Early in 1942, Mr. W. F. Sellers was appointed as Senior Entomologist; he was first stationed at Belleville but was later transferred to Riverside, where he started a long-term project for Australia on the parasites of the potato tuber moth. In 1945, work in the West Indies on the natural enemies of a tropical weed of the genus *Cordia* on behalf of the Government of Mauritius was assigned to the organisation by the Colonial Office, and Mr. Simmonds was transferred to Trinidad for this investigation, with headquarters in the Imperial College of Tropical Agriculture. In order to render as much service as possible to contributing governments, it was decided after the move to Canada to start the publication of the Parasite Catalogue.

The organisation was raised to the status of a Bureau in 1946. Early in 1947, work was re-opened on the continent of Europe by Mr. Sellers, who made a survey, in company with Dr. Gordon Bucher, seconded from the staff of the Belleville Laboratory for this purpose, of the parasites and diseases of certain insects allied to the Canadian spruce budworm. Following this survey, Dr. L. Mesnil was appointed to the staff and set up a laboratory near Zürich, Switzerland. At the beginning of 1947, at the urgent request of the Bermuda Government, the Director and Mrs. Thompson spent six months in Bermuda making an intensive effort to effect the biological control of certain imported scale insects to the Bermuda cedars. This long absence from headquarters interfered very seriously with the conduct of the work of the Bureau, and about the middle of 1947 authorisation for the appointment of Dr. G. C. Ullyett was obtained from Council. Dr. Ullyett spent the remainder of the summer in Bermuda and was transferred in the autumn to the headquarters at Belleville.

Since the expansion of the work necessitated more ample space, and contact with the authorities, library and collections in Ottawa, the office was transferred in the autumn of 1948 to the Science Service Building of the Department of Agriculture in the capital. Here free quarters, which were remodelled without cost to the organisation, were provided by the Canadian Department of Agriculture.

By 1949 the work for Bermuda had extended far beyond the capacity of any quarters that could be provided for our organisation by the Citrus Experiment Station at Riverside, California, and, with the assistance of the Bermuda Government, a very satisfactory laboratory was built about seven miles away at Fontana. In 1950 the South American laboratory was closed and Dr. Lloyd was transferred to California to assist Mr. Sellers.

In 1951 the title of the organisation was changed to the Institute of Biological Control, since its work is much more similar to that of the other two Institutes than to that of the Bureaux.

In 1951, after discussion at the 1950 Commonwealth Agricultural Bureaux Conference, the Food and Agriculture Organization of the United Nations assigned a project to the Institute on behalf of the Government of Yugoslavia. For the Canadian side of the work on this project, a small field laboratory was built with the permission of the Department of Agriculture on the grounds of the Central Experimental Farm, on which the Science Service Building, now housing the Institute, is situated. Temporary assistants were taken on for the summer for the F.A.O. work.

In the same year the Colombo Board of Canada assigned funds to finance a survey in India and Pakistan with a view to establishing Institute laboratories there. The representatives of India and Pakistan had at various times put forward suggestions that laboratories should be established in these countries in order to assist the development of biological control work; they offer very good facilities for obtaining parasite material not existing elsewhere. The survey was made by Mr. Sellers in 1952. Negotiations regarding the establishment of the laboratories are now practically completed, and it is probable that building work will start some time in 1954. The present plan is to establish the Pakistan station in Rawalpindi and the Indian station in Bangalore. It is hoped that Indian and Pakistani entomologists can be found to handle the work in these stations.

While he was on the Colombo Board survey, Mr. Sellers, with permission of Council, visited East Africa in order to discuss with entomologists there the suggestion some of them had made for the establishment of a biological control laboratory of the Institute in that region. A representative of the Colonial Office stated during the discussions at the 1950 C.A.B. Conference that they might be able to provide quarters for the work. However, nothing definite has happened up to the present in regard to the East African station.

In 1951, to assist in the much expanded work, Mr. F. D. Bennett was appointed to assist Dr. Simmonds in Trinidad and Dr. V. Delucchi to assist Dr. Mesnil in the Zürich Station, and in 1954 Mr. D. Groves was appointed to assist the Director at headquarters. In the autumn of 1951, after a gradual decline in health, Dr. Ullyett most regrettably felt obliged to resign and return to South Africa, where he died in November. He had made many important contributions to the theory of biological control and his death was a severe loss.

The effect of the various changes described may be gathered by comparing the receipts for special projects during the period of 1944 to 1949 with those of 1949 to 1954. During the first period the average yearly receipts for projects amounted to about $31,000, while during the period from 1949 to 1954 the average yearly receipts were about $75,000. In 1950–51 the sum of almost $100,000 was received for special work in addition to the basic contributions provided by governments.

In addition to the practical work, the Parasite Catalogue has continued to make some progress, though it has several times been interrupted by resignations of the staff engaged in the work. Thirteen volumes have now been published, one is in press and four will probably be ready this summer. There is now a first-class librarian on the permanent staff for this work so it should go forward without any further interruptions.

To sum up, the development during the past twenty-seven years has been moderately satisfactory and in spite of several severe crises some progress has been made towards the realisation of the original objectives. However, the position is not yet entirely satisfactory. The original lay-out was adapted to the needs of the temperate units of the Commonwealth, but only to a very limited extent, since the United Kingdom is a very poor source of material compared to continental Europe. This lay-out has been transformed into one adapted to the needs of the great part of the Commonwealth and indeed to the entire world. This transformation has met with a response, indicating that it was strategically necessary.

However, the transformation has not been effected without some loss. The dispersal of the small staff over a great area has meant a loss in direction and also in the mutual assistance and discussion that is possible in a group concentrated under one roof. The staff has gained greatly in experience and in first-hand knowledge of crops and pests. On the other hand, the output of papers summarising the results obtained in the projects undertaken, and making available for clients or entomologists in general all the scientific information that can be collected in connection with projects, has very considerably fallen off. This is partly due to the fact that in the tropical and sub-tropical stations field-work goes on all the year, whereas when the service was located in the United Kingdom, field-work largely ceased in the winter months, which could therefore be devoted to research and writing up results. Another factor is the isolation of workers. The effect is bad, because the members of the staff tend to decline to the status of mere entomological express-agents if they cannot make a good scientific study of each project and write it up in a sound, well thought out paper. The status of the organisation as a whole, based on its contribution to its special subject, therefore tends also to decline. The general development of biological work is to this extent impeded.

The only remedy that can be seen for this is a substantial increase in staff, so that each member of it has time to write up one project while another officer deals with the next to come in. This staff increase is also necessary because the extension of the work over the world entails rather frequent and often lengthy journeys and absences from headquarters, such as the visits of the Director to Bermuda, Mr. Sellers to India, Pakistan and East Africa, Dr. Simmonds to the Seychelles, Dr. Lloyd to South America and West Africa, Dr. Mesnil to Yugoslavia, and Dr. Delucchi to Italy. During these journeys, the burden on the remaining members of the staff becomes unduly heavy and in some cases the work is greatly disorganised. The present complement of staff is eight, which is just about the number that was available for scientific work when the headquarters were in England with a far smaller field of work and far more time for research and writing up results.

If the Institute succeeds in setting up laboratories in Pakistan, India and East Africa, its coverage of the world will put it in a very satisfactory position to serve the Commonwealth in biological control projects requiring the collection and transfer of material from one country to another. It should be made clear that there is no intention to multiply the laboratories indefinitely, but it is more practical to increase the number of laboratories carrying small staffs than to move men over vast areas in search of material, for it then frequently happens that they are obliged to do without the equipment and the library and laboratory facilities that they should have to work efficiently. Consequently, even if laboratories are successfully established in Pakistan, India and East Africa, one must envisage the possibility of a laboratory somewhere in the Far East.

As the project figures indicate, the work assigned to the Institute has kept pace with its geographical expansion. In 1952–53, eighteen countries of the Commonwealth were served and 733 consignments of beneficial insects sent out, comprising over 400,000 individual insects. Since the organisation exists mainly to give service to the entomologists of the Commonwealth on projects that they themselves select and assign to the Institute, the figures indicate that its work is successful. Since the Institute for the most part simply accepts projects assigned to it and does not select them, and since its work usually ends when material has been placed in good condition in the hands of the entomologist asking for it, the responsibility for success and failure of biological control measures with which it is associated falls only to a limited extent on the Institute. However, the Commonwealth Agricultural Bureaux Conference in 1950 assigned to the Institute the task of collating the results obtained in work of this type in all the countries of the Commonwealth. Appeals for the relevant information were sent out some time ago, and the entomologists of contributing governments have responded in a very satisfactory way. It is hoped that when all the information supplied has been gathered together and supplemented by data which are now being collected, one will have a much more accurate idea than can be obtained from any available publication as to the general significance and value of the method of biological control in regard to insect and plant pests.

There is, however, one remark which seems worth making. The basic difficulty in biological control work is to make an accurate assessment of the economic effects obtained; for various reasons this is a great deal more difficult than the assessment of insecticidal treatments. Occasionally, if lucky, an outstanding success is obtained which is recognisable by the reduction of the pest to a level where it is so uncommon as to be negligible. More often, parasites and predators are successfully established and it is observed that they continue to increase up to a certain point, killing off a notable percentage of the hosts, though often, particularly with insects, not until the damage for the generation concerned has been done. In such cases, much tedious and troublesome work is required to determine just what has been accomplished from the economic standpoint. Such assessments have very seldom been made and in the majority of operations the economic achievement admittedly remains in doubt. Nevertheless, it seems that some light has been thrown on this matter by the investigations carried on in recent years, associated with the names of A. M. Massee, A. D. Pickett and the late G. C. Ullyett, which show clearly that the elimination of beneficial organisms by certain insecticides is followed by an increase in damage. These workers have thus demonstrated in a round-about way that the native parasites and predators of insect pests are often a great deal more important than might be imagined. As Mr. Sellers has pointed out, one ought to be fairly well satisfied if, by the introduction of the natural enemies of a pest, imported from the native home, one gets the same degree of control as existed in the country of origin. The investigations mentioned have shown fairly conclusively that this degree of control is not of negligible importance, so that if it can be duplicated, as not infrequently happens, one may believe that something useful to agriculture has been accomplished.

APPENDIX III

PROCEEDINGS OF COMMITTEES

A. GENERAL COMMITTEE

1. The Committee was constituted as shown on p. 8 and held meetings on 12th, 15th and 16th July.

2. The agenda placed before the Committee at its first meeting comprised the following items for discussion:—

- (i) A memorandum by the Director of the Commonwealth Institute of Entomology on the work of the Institute, covering the period 1948–54 (Appendix I).
- (ii) The Plant Quarantine Station at Kew Gardens.
- (iii) A memorandum by the Director of the Commonwealth Institute of Biological Control on the history and work of the Institute (Appendix II).
- (iv) Other business.

3. The recommendations framed by the Committee as a result of its consideration of the subjects on the agenda were submitted to the final plenary session of the Conference and embodied in the Conclusions and Resolutions that were finally adopted (pp. 10–13). A summary of the discussions that took place in the Committee is given in paragraphs 5–33 below.

4. Item (i) of the agenda was prefaced by statements of the action taken on a number of resolutions of the last Conference; where these concerned the work of the Institute they were dealt with by the Committee when considering the appropriate section of the Director's report. The matters considered under item (iv) of the agenda were as follows:—

- (*a*) Reviews of work in economic entomology in the Commonwealth countries (Appendix VI).
- (*b*) Research on pests of tropical cereal crops.
- (*c*) Research on pests of stored products in the tropics.

  Both (*b*) and (*c*) were discussed in open meetings of the Conference (see pp. 101 and 110), and the Committee was asked to draft resolutions for approval at the plenary session (Resolutions 22 and 23).
- (*d*) Supply and training of taxonomists.

  The resolutions drafted by the Committee on Taxonomy (see Appendix III B) were considered by the General Committee and submitted for approval at the plenary session (Resolutions 14–20).

Statements on Research in Progress in Commonwealth Countries

5. It was pointed out that although it had been recommended at the 1948 Conference that periodic brief statements respecting research work in progress in all Commonwealth countries should be sent to the Commonwealth Institute of Entomology, only two such statements had been received. Some members of the Committee felt that the lack of response suggested a lack of need, and that the additional reports might be an unnecessary burden on those producing them, but, after discussion, it was agreed that a simplified scheme would be valuable whereby the Institute would be enabled to provide, on request, information on what research projects were in train. It was therefore suggested that the Institute should circulate a request at yearly intervals to each country of the Commonwealth to furnish a list of current research projects in economic entomology, their location, and the names of those in charge of them (Resolution 8).

Research on Termites

6. The establishment by the Colonial Office of the Termite Research Unit, financed by Colonial Development and Welfare Funds, implements a recommendation of the 1948 Conference and was warmly welcomed by the Committee. It was explained that the primary task of the Unit is the study of the biology and taxonomy of termites, the systematic work being centred on the British Museum (Natural History) and the field work to date having been done chiefly in East Africa, although it was intended to extend this eventually to other colonies, outside Africa. It was suggested that the field investigations of the biology of termites provided useful opportunities for concurrent investigations of methods of control, particularly of termites as pests of agricultural crops. Information is already available on the control of termites as pests of structures and stored timber and further work on this aspect of the problem is going on in Australia, but their control as agricultural pests has been neglected. The Committee agreed that although biological and taxonomical research should continue to be the principal duty of the Unit, and although it should not be called upon to advise on control, it was desirable to take advantage of the opportunities for investigating the control of termites as pests of agriculture and forestry that the present field work provided, and that an additional officer should be appointed to the Unit for that purpose (Resolution 21).

Nomenclature of Insecticidal Chemicals

7. The Committee noted with approval the work of the Technical Committee of the British Standards Institution that deals with the names of pest control products, and welcomed the proposal that an international body should be set up to obtain further unification of names, especially as between those used in the United Kingdom and in the United States.

African Continental Quarantine

8. The Committee noted that although it was expected that the draft Phytosanitary Convention for Africa south of the Sahara would be signed early in 1954, further difficulties had arisen that might delay this for some months.*

Review of Applied Entomology

9. The Committee noted the continued rise in the circulation of the *Review of Applied Entomology* and discussed methods of dealing with the increasing volume of publications in economic entomology. It was suggested that the *Review* might be increased in size, but it was thought that, apart from the increase in the abstracting and editorial staff that this would necessitate, the *Review* would be of less real service than it is if its size were greatly increased, and that to increase the coverage by reducing the length of abstracts to such an extent that workers were driven to consult the original papers, would defeat the object of serving those without extensive library facilities.

10. This led to a suggestion that the abstracting of papers in well-known journals might be discontinued, on the ground that everyone sees them, but it was pointed out that this would make it impossible to give the cross-references that co-ordinate different results and opinions on a given problem, because some of the most important papers on it would not have been abstracted. It was explained that at present all the papers in the most important journals are abstracted, and an attempt is made to include abstracts of all the more important ones from the less well-known journals, but selection is applied to all other sources of literature, and interim and progress reports are seldom abstracted, as it is thought that the information contained in them will ultimately appear in full in scientific papers.

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* In the event, this Convention was signed on 29th July, 1954 by all Member Governments of the Commission for Technical Co-operation in Africa south of the Sahara.

11. While assistance would be given to abstractors if authors were to provide adequate summaries of their papers, and if editors were to follow the proposal (of the Committee on Abstracting) of the Royal Society and accept responsibility for seeing that these are true synopses, the difficulty would still remain that different journals abstract papers from different viewpoints because they cater for different clienteles. Resolution 4 resulted from this discussion.

Bulletin of Entomological Research

12. The Committee considered that, in comparison with other scientific journals generally, the reduction to twelve months of the period between acceptance and publication of a paper in the *Bulletin*, following the increase in volume size to 800 pages, is not unreasonable. The nature of the papers in the *Bulletin* reflects the trend of research in progress and whilst the journal was started as a medium of publication for Colonial entomologists, papers from overseas workers do not now necessarily have priority but are dealt with on their merits.

13. The opinion was expressed that some of the papers that appear in the *Bulletin* are unduly long and deal with subjects of too localised an interest, but it was pointed out that, despite the fact that some manuscripts are rejected on account of length and others returned to authors for reduction, further reduction could only be achieved editorially by the expenditure of a great deal of time. Whilst it was not felt that a formal editorial board was desirable, the Chairman suggested that members of the Committee might send the Editor names of those who might be prepared to give assistance where this was desired in special fields. The Committee felt that it was not necessary to make any new resolutions regarding the size and content of *Bulletin* papers, but it emphasised its support of the recommendation made by the 1948 Conference and embodied in the notes for authors on the inside cover of each issue of the *Bulletin*. This discussion resulted in Resolution 5.

Distribution Maps of Insect Pests

14. During the discussion on distribution maps of insect pests, Mr. W. Ruttledge was present as he is in charge of their production. It was agreed that it would be impracticable to indicate the distribution of pests on these maps by dots signifying the actual sites of the records, instead of by the present practice of a line enclosing the country or state within which the record occurs, because it is often uncertain to what locality within the territory a record refers. The delineation by countries is desirable in connection with plant quarantine, but the maps should be used with reasonable discretion in such cases, and action based upon them may require to be fortified by direct queries to the countries concerned.

15. The Committee strongly supported the present policy of basing the maps upon published records and on material in the British Museum collections and identification lists of the Commonwealth Institute of Entomology, as it considered that there would be great danger in including in the maps any records the origin and validity of which could not readily be traced and checked. Attention was drawn to the medium provided by the Plant Protection Bulletin of the United Nations Food and Agriculture Organization for the rapid publication of new records. It was also suggested that annual reports should contain indexes, to facilitate the search for pest records, and that territories should publish periodically check-lists of insects of economic importance (Resolution 6).

The Identification Service

16. The difficulties faced by the identification service of the Institute, and the larger question of taxonomic research in general, are dealt with in the memorandum (Appendix V A) that was discussed in open meeting (see page 69) and by the committee specially appointed at that meeting (Appendix III B). Resolutions 14–20 of the Conference, which resulted from these discussions, deal with the general problem

of taxonomic research. The position of the Institute's identification service was discussed in more detail by the General Committee. It was emphasised that there is in practice no overlap, as regards the groups studied, between the staff of the Institute and that of the British Museum (Natural History), who are in fact complementary to each other.

17. It was pointed out that the amount of work done for different regions depends entirely upon the amount of material that is sent in from them. In this connection, the following points were made by certain members of the Committee: that it was the endeavour in India to send only material that could not be determined at Delhi; that large quantities of material were being sent from Pakistan while that country built up her own reference collections; and that although Canadian material was at present almost entirely identified from collections in North America, it was evident that the services of the Institute would have to be utilised more than in the past for the extensive amounts of material from Europe used in connection with biological control.

18. It was agreed that, having regard to the greatly increased interest being shown in mites of agricultural importance, with a concurrent increase in requests for their identification, and to the fact that the number of workers on the taxonomy of the Acarina is so extremely small, it was a matter of the utmost urgency that a specialist should be appointed to the staff of the Institute to deal with this group. Furthermore, having regard to the future, it was agreed that two further specialists should be appointed to work in other groups to be selected at the discretion of the Director (Resolution 7).

Reviews of Work on Economic Entomology in the Commonwealth

19. The Committee was asked to comment on the decision to print the reviews of work on economic entomology that had been received from nearly all the countries in the Commonwealth, and to suggest possible methods of improving them in the future. Members agreed that these reports were a most useful record of work and that they certainly merited publication. It was pointed out that some of the reports contained a list of publications by members of the Departments of Entomology concerned or a bibliography of references in the text, and that such a documentation of work could usefully always be included. It was explained that, in the case of Canada, such lists are available in the Annual Report of the Director of Science Service and, being very lengthy, were not included in the Review. It was agreed that, after further study of the whole subject, a memorandum on the size, composition and arrangement of future reviews should be prepared and circulated by the Institute (Resolution 24).

Plant Quarantine Station at Kew

20. The Committee had before it a memorandum concerning the special greenhouse that has been in operation at Kew since February 1951 for the quarantine of planting material in transit from one part of the Commonwealth to another. The cost of erection and maintenance has been met from Colonial Development and Welfare Funds, and it is hoped that it may be possible to continue this arrangement until the end of March 1957, but after that date, alternative means of financing this service to the Commonwealth will have to be found. It is estimated that by then the annual cost of maintenance may amount to £1,100.

21. The Committee agreed that, in view of the importance of taking all possible measures to ensure that any planting material for introduction should be free from pests and diseases, particularly virus diseases, it is desirable that the services of the greenhouse should be maintained, and suggested that the matter should be considered by the Commonwealth Agricultural Bureaux Review Conference in 1955, with a view to a decision by the Commonwealth Governments on the possibility of meeting the small cost of upkeep of the service (Resolution 25).

Biological Control

22. The Committee had before it at its second meeting a memorandum on the history and work of the Commonwealth Institute of Biological Control, which had been prepared by the Director, Dr. W. R. Thompson, and circulated to delegates. A shortened version of this is given in Appendix II. This meeting of the Committee was attended by Dr. Thompson and certain delegates with special interests in biological control methods (p. 8), and it was invited to consider, in particular, the proposals to establish sub-stations of the Institute in India, Pakistan and East Africa.

23. It was explained that the proposals for the sub-stations in India and Pakistan had been under consideration for some time, that negotiations were nearly complete and that it was hoped that work on them might start this year. The arrangement contemplated was that the stations should be built for the Governments of India and Pakistan with funds provided by the Canadian Government under the Colombo Plan and leased to the Commonwealth Institute of Biological Control. The staff would initially, it was hoped, be seconded from the entomological services of India and Pakistan, respectively, but after a period of 18 to 24 months would be taken onto the strength of the Institute.

24. A further memorandum, which had been prepared and circulated by Dr. R. H. Le Pelley on behalf of the East African Specialist Entomological Committee, formed under the auspices of the East African Agricultural and Forestry Research Organisation, set out the reasons in favour of the establishment of a sub-station of the Commonwealth Institute of Biological Control in East Africa, and included a list of insects of agricultural importance that occur both in that region and outside it.

25. This memorandum pointed out that the Committee set up by the 1948 Entomological Conference to consider the organisation of biological control in the Commonwealth had recommended, *inter alia*, the establishment of a station in East Africa, and that the 1950 Review Conference had authorised the Executive Council of the Commonwealth Agricultural Bureaux to increase the number of field stations as might be desirable and so far as financial provisions might permit. Mr. W. F. Sellers, of the Institute's staff, had visited East Africa in 1952 and had reported favourably upon the possibilities that this area affords to help the Commonwealth. Africa had a fauna of a richness seldom fully appreciated, and East Africa had a very wide range of physical conditions and also enjoyed good air connections. Dr. Le Pelley had reason to believe that the project would be supported at a high level in Kenya, where temporary laboratory facilities could be offered to assist in the early stages. Dr. Thompson indicated that provision would be made for the creation of this sub-station, and for a staff of two entomologists, in the budget presented to the 1955 Review Conference. An expression of technical opinion on all three projects was sought from the present Conference.

26. The discussion that took place centred round two points, (*a*) was it intended that the three stations in question should primarily benefit the countries in which they were situated, or the rest of the Commonwealth, and (*b*) would the work at these stations be wholly concerned with the collection, shipment and distribution of parasites and predators, or would it extend to investigations ancillary to the projects being handled, or to basic research on the biological factors that influence the size of insect populations.

27. Dr. Thompson explained that although the sub-stations of a biological control organisation are usually established in order to benefit countries other than those in which they are situated, the two in India and Pakistan will be of direct value to those countries by channelling useful material into them, as well as advancing

the subject generally. They will, however, work in the same way as other stations of the Institute, serving as centres from which useful material from the Indian sub-continent can be collected and shipped to other regions in the Commonwealth, and this principle had been accepted by the countries concerned.

28. Some doubts were expressed whether it was necessary to set up permanent research stations rather than to send entomologists to wherever was necessary, and whether it was desirable to have two stations within the Indian sub-continent when there were very large untapped areas elsewhere in Asia, and in Africa. It was pointed out, however, that the matter had already been virtually settled at the administrative level. It was explained that the maintenance of the stations by the Institute would depend on their practical value as centres for biological control work in association with local agencies and on behalf of the Governments contributing to the Commonwealth Agricultural Bureaux. The Committee accepted this explanation and agreed that the establishment of the two stations might be regarded as a very large-scale experiment, which should be reviewed at the next Conference.

29. It was remarked that the memorandum proposing the establishment of a sub-station in East Africa did so apparently on the grounds that other Commonwealth countries would thereby be enabled to tap for their own benefit the large reservoir of beneficial insects existing in central Africa. The fact that this proposal came from East Africa, and not from the countries that were going to benefit, might suggest an element of wishful thinking. Furthermore, the purpose of the long list of pests that accompanied the memorandum was not very clear; many insects were included that are not and could not be biologically controlled. It was suggested by more than one speaker that a definite list of projects with which the station could deal should be drawn up.

30. Dr. Le Pelley explained that the establishment of a sub-station in East Africa would materially assist entomologists at present working there, by relieving them of the very considerable amount of work they were now being asked to do in providing insect material for shipment elsewhere. This demand in itself indicated that the importance of the African parasite and predator fauna was already recognised, notably by the United States. There would be a two-way traffic of material through the station, and the introduction of useful insects into, as well as their export from, Africa would be facilitated.

31. Other speakers pointed out that there were many problems in Africa in connection with biological control that had not been adequately investigated because of lack of facilities, that the pattern of agriculture there was changing and in consequence new pest problems arising, and that as a result of air transport these might be expected to increase; the station would also certainly be of value to such diverse areas as Mauritius, India and the region of the Pacific. In importing parasites to New Zealand and Australia from the northern hemisphere the problem of synchronising life-histories with seasons arises, and it was suggested that a conditioning station in Africa might be of value.

32. The discussion showed it was generally felt that it was not enough for biological control stations to collect and ship parasites and predators; it was desirable that proper surveys should be made of the part played by these insects in their regions of origin and of the extent to which they became effective in the regions to which they were introduced; these elementary necessities were often neglected, sometimes through sheer lack of time, thus introducing a haphazard element into biological control that tended to undermine faith in the whole method. Furthermore, although the view was expressed that it is not possible to predict the effect of moving an insect from one region to another, it was generally felt that there was a need for more fundamental work on the mode of action of biological control, beyond the ancillary investigations necessary to any particular project. It was hoped that the Institute might be able to undertake such work.

33. Dr. Thompson emphasised that the position of the Institute was that it existed to meet demands made on it by economic entomologists; the Institute did not initiate or draw up lists of projects. Moreover, although it could and did give guidance and advice on projects it was asked to handle, it could not insist on such advice being carried out. He, equally, deplored the tendency for sub-stations of the Institute to become mere express agencies, but this was made inevitable by a deficiency of staff, which was at the same level as twenty-seven years ago, although the organisation, in order to give better service to the Commonwealth, had now spread out to tropical areas where the field work was continuous and gave the staff no seasonal break during which work could be written up. If the Institute was to do the research ancillary to each project that all agreed was desirable, an increase of staff was essential. Further discussions on this point took place, and the results of these, and the views of the Committee regarding the subject of the proposed new sub-stations and the relationship between the work of the Institute and basic research upon biological control, are summarised in Resolutions 9–13.

B. COMMITTEE ON TAXONOMY

This Committee was set up as a result of the discussion on the supply and training of taxonomists that took place in open meeting on 9th July (page 69), when Dr. W. J. Hall introduced a memorandum on Commonwealth resources for the identification of insects of economic importance that had been prepared by the Commonwealth Institute of Entomology and circulated to the Conference (Appendix V A). The Committee met the same day and consisted of Prof. O. W. Richards (Chairman), Dr. Taskhir Ahmad, Mr. A. B. Baird, Mr. I. F. B. Common, Dr. R. H. Le Pelley, Prof. J. W. Munro, Mr. H. Oldroyd, Mr. N. D. Riley, Dr. J. Smart and Mr. H. L. G. Stroyan. Dr. W. J. Hall, Mr. E. O. Pearson and Capt. H. S. Bushell also attended the meeting. The recommendations of this Committee, after being considered in draft form by the General Committee, were submitted to the final plenary session of the Conference and adopted as Resolutions 14–20.

APPENDIX IV

PROCEEDINGS OF THE OPEN MEETINGS

CONTENTS

SUBJECTS OF DISCUSSIONS	AUTHORS OF OPENING PAPERS	PAGE
Recent Developments in the Use of Insecticides on Field Crops.	H. G. H. Kearns ..	35
Recent Developments in the Use of Insecticides from Aircraft.	D. Yeo	44
	R. C. Rainey ..	48
The Effect of the Use of Chemicals on the Balance of Animal Populations.	A. M. Massee ..	53
The Development of Resistance to Insecticides ..	J. R. Busvine ..	60
The Supply and Training of Taxonomists ..	W. J. Hall	69
The Estimation of Real Losses from Insect Pests	I. Thomas	75
	A. H. Strickland ..	78
	Q. A. Geering ..	83
The Biological Control of Insect Pests	W. R. Thompson ..	89
The Biological Control of Weeds	J. R. Williams ..	95
Pests of Tropical Cereal Crops	H. F. Barnes.. ..	101
	J. Bowden	104
Developments in Work on Pests of Stored Products	G. V. B. Herford ..	110
Problems of Forest Entomology	R. C. Fisher	117
	F. T. Bird	122
Developments in Termite Research	W. V. Harris ..	126
Developments in Locust and Grasshopper Research and Control.	L. G. Putnam ..	133
	B. P. Uvarov ..	137
Recent Developments in Tsetse Research and Control.	C. H. N. Jackson ..	143

DISCUSSION ON RECENT DEVELOPMENTS IN THE USE OF INSECTICIDES ON FIELD CROPS

Chairman: Sir Geoffrey Clay, K.C.M.G., O.B.E., M.C.,
Agricultural Adviser to the Secretary of State for the Colonies

The CHAIRMAN said that it was intended to confine the discussion to annual and semi-annual crops, as time would not permit the inclusion of tree crops. The development of new insecticides had brought about a new era in the treatment of colonial crops, and he hoped to hear views on the feasibility of using them to dust or spray large areas of native-grown crops, or whether their use would have to be largely confined to European estates. He then called on Dr. Kearns to read the opening paper.

Some recent Developments in the Use of Insecticides on Field Crops

By H. G. H. Kearns
University of Bristol Agricultural and Horticultural Research Station, Long Ashton

The invitation to open this discussion was accepted with some misgiving, as the data within the Commonwealth concerning the application of insecticides to field crops are somewhat scanty. The real worth of control measures cannot be assessed unless they have been applied on a large scale, and they have not been so applied except in the United States and on cotton in the Sudan.

Until a few years ago, no serious thought was given to widespread insecticidal treatment of field crops, as neither suitable insecticides nor machinery was available. This Conference provides an excellent opportunity of hearing the views of entomologists from many territories who have first hand contacts with the problems. No attempt has been made to cover the subject in any detail; only the bare bones are given as reminders to the Conference.

Crops are grown for profit, and the higher the cash returns the greater the chances of justifying the expenditure and toil associated with chemical control of an insect. Spraying or dusting of field crops is not attempted until it becomes a painful necessity, and, in common with plantation crops, the problems arise from man's cultural methods of mass production. When a new crop is introduced into a fresh area, it is only a matter of time before a major problem develops, such as that presented by the Noctuids and sucking bugs attacking seed beans in Tanganyika. In other cases, the repeated use of the same insecticides favours the rapid development of resistant species, such as the red spiders on fruit crops. The more potent the insecticide and the wider its range of toxicity, the greater the risk of painful biological repercussions. Insecticides with long-lasting residual toxicities on exposed plant surfaces must be treated with the greatest respect. Knowledge of the relationship between insects and insecticides on plant tissues is extremely scanty and must be increased as it is essential for the development of spraying techniques. Faults made in the selection of insecticides in a spray programme on plantation crops are cumulative and the results appear in subsequent years. With field crops, the repercussions of the misuse of insecticides are not as a rule so painful. The post-war development of a multitude of synthetic insecticides, more especially in the United States, has tended to make the farmer and his advisers regard them as the answer to all insect problems. Fortunately, this state of affairs is gradually improving with an increase in knowledge of the insect ecology of crops grown in man-made environments. Dr. Massee and Mr. Pickett will no doubt enlarge on this important aspect of economic entomology. Our range of insecticides is adequate to meet nearly all needs, and the next phase of development must be one of learning how to use them.

The control of insect pests is considerably more difficult on field crops, such as sugar-cane, cereals, cassava, tobacco, cotton, beans or brassicas, than it is on plantation crops, such as coffee, tea, citrus or pineapple, which are essentially luxury crops.

It is technically more difficult, as the method of cultivation is often ill-suited to the use of spraying machinery, and economically so, because the margin of profit limits what can be afforded. An enormous acreage of the world's basic food crops is grown by peasant farmers. The yields are at such very low levels owing to faulty cultural methods that any attempt to introduce measures for insect control is putting the cart before the horse. There are occasional exceptions when concentrated efforts to reduce easily controlled pests are perhaps worthy of trial. For example, LePelley, Swaine and others in Africa have shown that the widespread and devastating maize stalk-borer can be controlled by shaking a little cheap DDT dust into the funnel of the growing plant at the correct time.

However, this " little shaking " is no easy matter to get over to the African. With a primitive agricultural community, there is no hope of substantial improvement in farming methods unless it is organised on a co-operative basis that offers glitteringly obvious benefits. It therefore seems that many decades must pass before insecticides find their way on any scale into the cultural practices of the uneducated peasant farmer.

A brief mention of a few of the synthetic insecticides may be a useful reminder for this discussion. Of the chlorinated hydrocarbons, DDT and BHC are the most widely employed, but aldrin and dieldrin find an increasing use, especially abroad. Chlordane is not used on a commercial scale in the United Kingdom, as it offers no advantages over DDT and BHC, and toxaphene also has only a limited use. DDT and BHC are available as dispersible powders; many of these contain somewhat indifferent wetters, which is of less importance with the BHC on account of its fumigant action. Emulsions are available and some of them are compatible with other spray materials. Preparations of γ BHC are becoming much more widely used, as they reduce or avoid taint problems.

Combinations of DDT and γ BHC in the form of emulsions with high wetting properties are valuable general-purpose insecticides, and in this instance little is gained with many insects, certainly on fruit, by using concentrations higher than 0·025 per cent. DDT and 0·006 per cent. γ BHC. Aldrin and dieldrin are available as dispersible powders or emulsions. Aldrin is not very persistent, whereas dieldrin is extremely so, which is one of the reasons for its value against soil insects; it may replace DDT for a number of purposes.

Of the organic phosphates, TEPP and parathion are rapidly falling out of favour because of the high hazards to health and the need to use comprehensive and exhausting protective clothing. TEPP is an excellent contact aphicide, and it is non-persistent and hydrolyses in 24 hours, but it is extremely dangerous in the concentrated form, as it is water-soluble and rapidly absorbed by the skin. Parathion compounded as an emulsion is considerably more persistent than TEPP, but crops in summer weather are free from harmful residues (0·1–0·3 p.p.m.) 2–3 weeks after application. It is toxic to a wide range of insects and to red spiders, in fact it is a " kill-all ", and it is able to kill Aphids through leaf tissues. It is now avoided as much as possible, and as soon as acaricidal ovicides are well established it may find few uses. It is not suitable for application by unskilled labour, and it should not be used without full appreciation of its residual hazards.

Of the organo-phosphorus systemics, schradan, Systox, dimefox and Isopestox are used on an increasing scale. Schradan is finding an increasing use on a number of crops in the United Kingdom, whereas Systox is preferred in the United States and its use is confined to cotton. Dr. Ripper and his colleagues have played a major part in the commercial development of these materials, and an extensive literature on their use and properties has been published during the past five years.

Schradan is an endolytic systemic that breaks down within the plant into degradation products, most of which are not toxic. It is the most selective of the systemics, killing Aphids, Coccids, thrips and red spiders and leaving predators unmolested.

It does not kill insects living within the plant. It does not kill Aphids with sufficient rapidity to prevent the infection of a plant with a virus but it materially reduces the spread of infection. There is a satisfactory method of analysis.

Systox contains two compounds that are endometatoxic and therefore change within the plant into other toxic materials before final decomposition. It has not found favour in the United Kingdom, as insufficient is known of the mammalian toxic hazards. It has an appreciable contact action as a surface insecticide. There is no satisfactory method of analysis.

Dimefox, the principal component of Hanane, is endolytic and its commercial use has been confined to root and tree-bark application. It can be sprayed on foliage but it is more conveniently applied by way of the soil. Isopestox was synthesised by Pest Control Ltd. It is highly toxic to man, and it should be applied to the soil in water-soluble capsules. It has not been so widely used as schradan.

Our knowledge of the systemics is still in its infancy and, in common with any new insecticide, their true worth can be ascertained only after extensive use. They owe their success to their selectivity and mode of distribution within the plant, and the long duration of their effectiveness. Their use has been confined to the control of the less active sucking insects, in particular Aphids and Coccids. Their mode of distribution within the plant makes it possible to reach insects feeding in sites inaccessible to most other insecticides. These characteristics make them a most valuable tool for the entomologist and simplify spraying problems.

It is unfortunate that the successful compounds to date are highly toxic to man. Their application must therefore be confined to the user who is fully conversant with the hazards to himself and is most conscientious in ensuring a safe lapse of time between the treatment and sale of an edible crop. This safety period varies with the material, crop and climate.

The rate of uptake and translocation of a sytemic varies with the material, the species and physiological state of the plant, and unknown factors. My colleagues, S. H. Bennett and W. D. E. Thomas, have told me that the greatest chance of obtaining consistent results is by soil treatments, as there is always an element of uncertainty with leaf applications, so that the control of susceptible insects on the same kind of crop may vary from the spectacular to unsatisfactory.

Another important development has been that of the ovicidal acaricides, and the most promising of these are p-chlorophenyl p-chlorobenzenesulphonate (Ovotran) and p-chlorobenzyl p-chlorophenyl sulphide (Chlorparacide). At the low concentrations of about 0·025 per cent., both are able to kill summer eggs of mites by diffusion through a leaf, and the sulphide kills winter eggs when applied at the higher concentration of 0·057 per cent. just before they hatch. There seems little need at the moment for their use on field crops, with the possible exception of beans.

A few examples of the experimental and commercial uses of insecticides against pests of field crops are of interest. The control of wireworms attacking cereals by means of BHC seed-dressings is an outstanding example of a simple and effective method. In the United Kingdom, D. W. Wright has shown that the pea moth (*Laspeyresia nigricana*) is controlled by the application of 0·25 per cent. DDT emulsion at the rate of 100 gallons per acre at the early pod stage. He has also found that the carrot fly (*Psila roseae*) can be controlled in some cases by spraying the hedgerows and other resting sites of the adults around the crop with DDT, and in severe infestations by protecting the crop by a small-volume application of γ BHC at about 8 oz. per acre. Seed-dressing with γ BHC at $\frac{3}{4}$ oz. per lb. seed also gives a substantial protection against the first brood of this fly. The brassica pollen beetle (*Meligethes aeneus*) is successfully controlled with DDT emulsion applied just before flowering by a spray technique worked out by Pest Control Ltd. in which a special high-clearance tractor is used. Flea-beetles on brassicas can be controlled by dressing the seed with γ BHC or by small-volume application of DDT emulsion at $\frac{1}{2}$ lb. DDT per acre.

Schradan at 0·3 per cent. in 100 gals. water per acre is used extensively with satisfactory results for the control of Aphids on sugar-beet and brussels sprouts. In the case of brussels sprouts, not less than 4–8 weeks must elapse between the application and first picking.

In the colonial territories, it has been shown that the sugar-cane root weevil (*Diaprepes abbreviatus*) in the West Indies can be controlled by including aldrin in the fertiliser. The sugar-cane froghoppers (*Aeneolamia*, etc.) can be controlled by applications of BHC dusts or emulsions, and these are used as routine measures when necessary. In Tanganyika, A. J. Jones has shown that Noctuid caterpillars and sucking bugs attacking seed beans can be controlled by DDT emulsions and Jepson and others have found that BHC placed in the planting furrow of cane gave a very substantial increase in yields by killing or repelling chafer larvae (*Cochliotis* sp.). The maize stalk-borers, especially *Busseola fusca*, can be substantially controlled by correctly timed placement of DDT dust in the funnel. BHC used in conjunction with a mixed placement-fertiliser has protected sunflower from termite attacks. In the Sudan, DDT spraying carried out on a very large acreage has given a satisfactory control of the jassid (*Empoasca lybica*) on cotton.

The compounding of insecticides receives scant attention from many experimental workers. Through force of circumstances, much of the work abroad is carried out with proprietary products of incompletely disclosed composition. It would be preferable to use materials of known specification, as this is the only way of ensuring reasonable replication of results with the same toxic ingredient. The performance of the toxic ingredient may be materially altered by its physical constitution, which controls its distribution on the foliage and on the insect. To cite one example, DDT in the form of a wettable powder as normally prepared fails to control Aphids, whereas it can be incorporated in an emulsion to give a complete kill at a much lower concentration. It is appreciated that special facilities are necessary for the preparation of some materials, such as dispersible powders and dusts, but these difficulties should be overcome for research purposes. The use of a range of standardised test materials would at least make it less difficult to compare the results of different workers, and assist manufacturers to make satisfactory preparations having similar characteristics.

Much of the excellent work carried out on control measures fails owing to faulty methods of putting them into large-scale practice. The application of insecticides to field crops is full of difficulties; little can be done with ground machinery on many crops because extensive mechanical damage may be caused once the crop is dense and in full growth. Unless, therefore, special high-clearance machines are available, treatments must be largely confined to the crop in the early stages of its establishment. Again, the habit of growth of the crop often makes it most difficult to deposit the insecticide at the correct site.

Field crops are grown under three different systems; the first of peasant farming in small mixed holdings, which probably represents the greatest acreage, with extremely low yields; the second of organised co-operative peasant farming, such as occurs in the Sudan for cotton and in parts of the Belgian Congo; and the third of organised estates, the two latter systems giving high levels of yield.

The equipment for applying insecticides to field crops varies from primitive hand-dusters to power-operated ground spraying machines and aircraft. Special high-clearance, self-propelled machines that are under development in the United States may overcome some of the difficulties associated with the use of tractors and the normal type of row-crop tractor machine. The choice of equipment depends largely on the lay-out of the crop, terrain and the type of farming. Often, however, dusts are used as a means of introducing a control measure, and a change-over is made to spraying as experience is gained.

Dusting owes its survival to the potent insecticides, such as DDT and BHC. At best it is not an efficient method of using a toxic material, the distribution of the insecticide is spectacular but by no means uniform, it fails to find its way between overlapping foliage, and adhesion to plant surfaces is poor. Its advantages, especially under many tropical conditions, are that it avoids the need for water as a carrier and permits the use of simple power machinery, which, if well designed, can withstand hard usage with little maintenance. It may be regarded as satisfactory if a high degree of control is not required or if the insect is very vulnerable and it therefore fits in well with the requirements of many tropical problems. Nevertheless, it is probable that small, power-driven mist blowers using small volumes of highly concentrated material will replace power dusters, as they offer higher efficiency at no great increase in weight or mechanical complications.

There are two principal methods of compounding dusts, by extensive milling and mixing-together of the inert carrier and the toxic material, and by spraying the toxic material in a solvent on to the carrier. Numerous techniques are developed for the mixing procedure according to the nature of the materials. The main aims of the manufacturer are to produce a dust that will be free flowing in the dusting machine, sufficiently dense to be applied without undue waste, and that will store well. Very little is known about the behaviour of dusts in relation to particle size and shape, and formulation. G. A. Wheatley showed that, with talc as the carrier, a solvent-prepared DDT dust was much more efficient than a ball-milled one. On the other hand, other workers have found there was little to choose between the methods of manufacture. These differences are probably due to the use of materials of different physical properties.

Recommendations of concentrations vary from 1 to 5 per cent. for DDT or BHC (13 per cent. γ isomer), and the choice will depend on the efficiency of the particular formulation. Often 2 per cent. is used at 10–15 lb. per acre.

Hand application of dusts is the most efficient, as it ensures the best chances of correct placement with the minimum of waste. It is also possible at a stage of crop growth at which power machines would cause devastating damage. When labour is cheap and plentiful it competes with power dusting on some field crops. The most simple form of dusting consists of shaking a porous bag over the plant; thus one acre of the " funnels " of young maize plants can be treated in eight hours in Africa at a labour cost of about 2*s*. An improvement on the bag is the very simple concertina-action duster designed by Swaine in Tanganyika. More complicated hand dusters are the rotary and the diaphragm types. The rotary must be well made and corrosion-proof to stand up to hard work and it is therefore relatively expensive, costing some £10–12. It must be well treated, and so must be used and maintained under supervision. There are waves of demand for the perfect rotary duster that never seem to develop into substantial orders. The diaphragm knapsack duster has much to commend it for peasant use as it can be cheap and of simple construction and maintenance, but the existing models are much too flimsy and distort when sat upon, which is their normal treatment. Many rotary dusters are used under supervision on native-owned cotton in the Belgian Congo, but it now appears that it would be preferable to use sprays if reliable small-volume knapsack equipment could be designed, despite all the difficulties of water haulage. It is calculated it would be practicable if as little as 8–10 gals. could be applied per acre.

Power-operated dusters may apply the dust by forceful application on to a nearby target or more usually by drift. In the second case, the principal function of the machine is to discharge a required amount of dust at a uniform rate into a prevailing breeze. A fan with a delivery rate of 2,000 cu. ft. air per minute at 60–70 m.p.h.

velocity is adequate, and little is gained by using larger sizes at normal tractor speeds. The distribution of the dust depends on its specification and the behaviour of the prevailing wind, and it is therefore necessary, each time the duster is used, to adjust the rate of flow to suit the effective swathe-width. The fan must be rugged and simple in design, and the dust should be fed into the vacuum created by it; all complicated agitators should be avoided, as these invariably lead to packing of the dust, especially if it is slightly over-moist. The assembly should be fitted with sealed ball-races, which require no attention except at infrequent overhauls. The whole unit may be self-powered, with the fan direct-driven and mounted on a suitable trailer with an adjustable-width axle. Alternatively, the dust unit may be mounted direct on to a tractor and driven from the power take-off; this arrangement has much to commend it, as the outfit is much more readily controlled in a row crop and far less damage is done to the plants.

The application of sprays to field crops involves the use of water, and many recommendations are based on the application of about 100 gals. per acre. This involves the carting of a very large volume of water on a big acreage, which is generally impracticable with most tropical crops. The effective application of considerably smaller volumes per acre involves the use of highly concentrated sprays and of nozzles with small apertures emitting enough small droplets to cover the target adequately. Small-aperture nozzles are likely to become blocked, and extreme care is therefore necessary to design a filter system that provides a full protection for them. Dispersible powders, unless specially prepared, should be avoided with small volumes as they cause blocking by aggregation on the filter gauzes; the finer the mesh of the gauze the greater the trouble. General experience suggests that 20–25 gals. per acre provides the least trouble with satisfactory results, but considerably smaller volumes are practicable provided that the machine is designed for the work.

Pneumatic knapsacks can be used successfully to apply small volumes of concentrated sprays on field crops. Their success depends almost entirely on devising means of eliminating blockage of the nozzles. On account of the relatively low working pressures, single-hole, ceramic, fan-spray nozzles are preferable, together with easy means of cleaning and replacing them. The pressure-retaining or, better, the compressor-filled pneumatic knapsack has still much to commend it, especially if labour is plentiful, provided it is used under competent supervision. Many of the complaints made about the faults of knapsacks are due to lack of experience in simple maintenance problems. It should be appreciated that spraying equipment has an extremely arduous life and troubles should be reduced by routine maintenance.

Power-operated field-crop sprayers are of three types, the tractor-mounted, the tractor-trailer and the self-propelled; the last is available only from the United States or operated by contractors. The tractor-mounted type is designed for the application of small volumes; the tractor-trailer type is in most cases driven by the power take-off and may be used dual purpose for applying either small or large volumes. They may be fitted either with gear or centrifugal pumps operating at 75 lb. per sq. in., or with high-pressure plunger pumps operating at 200–400 lb. per sq. in. The plunger pumps cost considerably more but the higher flow pressure, which need not exceed 200 lb. per sq. in., materially assists in the application of insecticides to difficult sites, such as beneath the canopies of foliage. Gear pumps must be treated with care, as abrasion and faulty lubrication will rapidly reduce their efficiency. The nozzles of these types of sprayers are arranged on booms varying in length from 10 to 35 ft. The nozzle may project the spray directly downwards or nozzles may be fitted on flexible drop-legs that can be adjusted to suit the height and make-up of the crop. Drop-legs can generally be used only when the crop is young, as there is then sufficient room for the formation of the spray pattern; at later stages of growth, severe mechanical damage may be caused to the crop.

Mist drift spraying of field crops is in the experimental stage. It avoids many of the complications involved in the use of large boom-sprayers, but it requires favourable wind conditions, which limits the periods in which it can be used on row crops. Its uses will be largely confined to cases in which deposition of the insecticides on upper and exposed portions would suffice. Coverage under the leaves is not generally satisfactory.

No mention has been made of the application of insecticides from aircraft, as it will be dealt with by other speakers, but this method has been used successfully on a large scale on cotton in the Sudan. An extensive use of aircraft on a wide range of field crops has developed in the United States, largely because of the difficulties associated with the use of ground machines. The terrain, the wide open spaces, the climate and cheap flying in the United States are particularly favourable for this method of application, and it remains to be seen to what extent it can be developed at an economic cost in the Commonwealth.

In conclusion, it must be stressed that the application of insecticides to field crops presents numerous technical, and with peasant farming, administrative difficulties. The cash returns per acre with many of the food crops are small and therefore offer little inducement to do anything. Spraying and dusting should be regarded as the last resource, when all less complicated methods of reducing crop losses have been fully explored.

There are many gaps in this very brief review, and I hope they will be filled by the audience who have so patiently listened to me.

Discussion

Prof. T. W. KIRKPATRICK expressed the opinion that the limiting factor in the use of insecticides on peasant crops was not the insecticides themselves, as these were excellent, and was only to some extent the lack of cheap and indestructible apparatus (as cheap dusters, at least, existed and there was much to be said for the muslin-bag method); it was mainly the difficulty of instructing illiterate peasants in the efficient operation of proved methods of control. He asked if any delegates would give their experience of extension work in this direction.

Dr. TASKHIR AHMAD said that, as Pakistan was mainly an agricultural country, considerable attention had been devoted there to the evaluation of the efficiency and economics of some of the newer insecticides, several of which had been tested against the Fulgoroids, *Pyrilla* spp. on sugar-cane and *Sogata distincta* on rice, and the field cricket, *Gryllulus domesticus.*

Pyrilla spp. are serious pests of sugar-cane in the North-West Frontier Province, infesting over 100,000 acres annually. When the insecticides were applied as sprays by ground machinery, effective control was obtained with as little as 0·06 gal. 20 per cent. endrin or 0·035 gal. 50 per cent. malathion per acre. The use of these insecticides instead of the BHC spray previously employed had reduced the cost of treatment by about 70 per cent. Malathion caused immediate knockdown and almost immediate mortality of nymphs as well as adults. An outbreak of *Sogata distincta* occurred in Sind during 1952 and reduced the rice crop by an average of 60 per cent. In 1953, when it was beginning to recur, sprays containing endrin or malathion were applied from the air or the ground, and 0·006 gal. endrin or 0·0035 gal. malathion was found to be sufficient per acre. *Aleurocanthus woglumi* on *Citrus* was effectively controlled by sprays containing 2–3 cc. 20 per cent. endrin or 50 per cent. malathion per gal. water. These experiments were carried out on a fairly large scale and indicated the possibility of increasing efficiency and reducing costs by the use of some of the new insecticides.

Dr. F. L. VANDERPLANK felt that it was asking too much to expect peasant farmers to treat their own crops. It would also be dangerous to do so, because inefficient treatment would assist in the building-up of insecticide-resistant strains of pests. It would be more economical and satisfactory for Government-controlled teams to treat all plant infestations and either charge directly for the service or recover the costs by a cess or export tax.

Dr. G. A. PATEL considered that there were three main difficulties in recommending the use of insecticides in India. The first was that reports of outbreaks were not received promptly so that relatively high concentrations of insecticides were required to control the insects in their later instars. The second was that the cost of insecticides was high in relation to the profits obtained, particularly in the case of cereals. The third was the difficulty of obtaining insecticides in villages where transport was a problem. It was not found difficult to educate the illiterate worker in the use of insecticides as this could be done by demonstration; what he needed was the insecticides and the appliances. The acreage under cereals was so large that it was not considered feasible for the Government to expend the huge amount that would be necessary to carry out the operations. It could, however, compel recalcitrant cultivators to do so by law. Laws to this end existed in various parts of India.

Mr. T. E. T. TROUGHT pointed out that there was a tendency among African peasants to regard the application of insecticides as a substitute, instead of a supplement, for good husbandry. He illustrated this by experience in the application of soil fumigants to tobacco beds in Uganda. No progress would be made until peasants had been instructed over a period of years on the benefits and methods of insecticide applications.

Mr. J. NICOL, referring to Dr. Kearns' statement that small rotary hand-dusters were used to treat cotton in the Belgian Congo, said that he had recently seen them in use for the control of Capsids on cacao trees in that country. He stressed that they were being used on very large and well-conducted commercial plantations, and not on the few and widely scattered native-owned plantations. Supervision on the commercial plantations was strict, and every tree was inspected and, if necessary, treated at 15-day intervals. One of the main difficulties experienced in the cacao farms of the Gold Coast was that very many of them were owned by absentee landlords. Cultural measures were scanty, and it was becoming apparent that the formation of official or semi-official servicing units would be necessary before any control measures that might be developed would be put into use.

Dr. R. H. LE PELLEY said that the control of the maize stalk borer in Kenya illustrated the evolution of methods of applying an insecticide on field crops. The first method was to apply 1 per cent. DDT dust in the funnel of the plant by hand; it was cheap, easy to apply and effective and was ideally suited to African farmers. It was hoped that the efforts being made to popularise this method in African areas would eventually be successful. It was still widely used by European maize farmers, but was to some extent being replaced by the application of DDT emulsions from the large boom sprayers generally employed for weed killing. A further method, still in the experimental stage, was the application of DDT from aircraft. The experiments had been carried out by the Colonial Insecticide Research Unit in collaboration with the Kenya Agricultural Department but would have to be continued if the method was to be developed.

Some other effective treatments used on field crops in Kenya were BHC seed dressings and aldrin soil treatments against a Dynastid of the genus *Heteronychus* on wheat. For the barley bulb fly (*Hylemyia*), the chafer grub (*Schizonycha*) and other soil-inhabiting insects, aldrin appeared to provide a useful treatment and would at least partly replace BHC.

Referring to machinery, Dr. Le Pelley appealed for the standardisation of sprayer parts, particularly such small parts as nozzle fittings. If manufacturers would not assist, some official body could, perhaps, arrange to secure a measure of standardisation. He also drew attention to the cheap and effective concertina duster designed by Mr. G. Swaine of Tanganyika. It cost some 6–7 shillings and was ideally suited to African peasant use.

Mr. A. D. PICKETT asked whether any work had been done in the United Kingdom or any other part of the Commonwealth on the long-term influence of systemic insecticides on the soil flora and fauna.

Dr. W. E. RIPPER replied that he knew of no long-term investigation, but in experiments on the influence of systemic insecticides on soil microbes, observations at the time of treatment and 4–5 months later showed that in reasonable circumstances the population was not altered in numbers or specific composition. Some soil fungi quickly metabolised the decomposition products of systemic insecticides and grew faster after an application. Modern insecticides in general had raised many ecological problems, and the need for biological and ecological work in connection with them was outstanding. It was essential to obtain control of insects, but it was also necessary to know when control should begin or stop. If, for example, a grower asked at what population level of the pea Aphid a spray should be applied, there was no paper to consult and the decision had to be left to his discretion. The problem was fraught with difficulties, but had to be faced since ecological reasons made it necessary to carry out as little chemical control as possible.

Dr. W. F. JEPSON said that the success obtained with DDT dust against the maize stalk borer in Kenya had not been matched in Tanganyika, probably because of ecological differences in the relation between the development of the crop and that of the moth. The peasant grower could easily be trained to use really simple apparatus, but, as he must apply the insecticide to every acre in every year, he must be convinced by demonstration of the actual loss caused by insects. Patient instruction on district plots seemed to be more promising than the operation of Government-organised teams in the development of insecticide application by peasants.

The CHAIRMAN considered that the feeling of the meeting was that the use of simple dusters was well within the power of peasant farmers if extension work and demonstration were adequate. The employment of low-volume sprayers would have to be an organised development with employees paid co-operatively or by the Government. He asked Dr. Kearns to sum up.

Dr. KEARNS stressed the importance of a point raised by Dr. Ripper; before the control began it had to be found when it was worth while. He agreed with Dr. Vanderplank that very extensive organisation was required before control by peasants was possible. Peasants would not buy insecticides or equipment, but large-scale control of pests in peasant farming could be financed " painlessly " through a central crop-sales organisation.

DISCUSSION ON RECENT DEVELOPMENTS IN THE USE OF INSECTICIDES FROM AIRCRAFT

Chairman: Dr. R. A. E. Galley, *Director, Colonial Products Laboratory*

The CHAIRMAN said that they had heard at the previous meeting that the use of synthetic insecticides called for new methods and techniques of application. They would now hear about what was probably the latest method of application. He called on Mr. Yeo and Dr. Rainey to read the opening papers, which would be concerned with the use of aircraft in the control of tsetse flies and locusts, respectively.

Aircraft Applications of Insecticides against Tsetse Flies and other Insect Pests in East Africa

By D. Yeo

Colonial Insecticide Research Unit, Arusha, Tanganyika

Since 1948, experiments have been carried out by the Colonial Insecticide Research Unit, Arusha, Tanganyika, to investigate the possibilities of using aircraft to apply insecticides for the control of some of the major insect pests in East Africa. Most of the work has been concerned with tsetse flies, but a start has been made with other important pests, and there has been fundamental work upon the meteorological and physical problems peculiar to this specialised use of aircraft.

Tsetse flies, because they infect man and his livestock with pathogenic trypanosomes, are a major obstacle to the development of many parts of tropical Africa. The scale of the problem may be judged from the fact that, in Tanganyika alone, approximately a quarter of a million square miles, constituting 75 per cent. of the total land of the territory, are fly-infested and are as a consequence unsuitable for balanced settlement. Direct control of the flies is one method of controlling trypanosomiasis, and it was logical to investigate the possibilities of achieving this by using the modern, highly toxic, synthetic insecticides. Since the areas involved are large, and are often inaccessible or difficult to travel through on the ground, aircraft suggested themselves as a means of disseminating the insecticide.

The control of human trypanosomiasis is of importance in East Africa, but more important is the control of animal trypanosomiasis. This is usually associated with the savannah woodland so characteristic of much of East and central Africa, and the most important vectors are *Glossina morsitans*, *G. pallidipes* and *G. swynnertoni*. It is with these species that we have been mainly concerned.

In principle, the adult fly, which is the only form that can be attacked with much promise of success, may be killed either by residual deposits, from which it picks up a lethal dose, or by " space sprays ", which have no residual action but rely upon an immediate deposition of the insecticide upon the insect. Methods using residual deposits have given useful results against *Glossina palpalis* (Woodcock, 1949; Wilson, 1953), which is confined to rivercourses and the shores of lakes and is an important vector of human trypanosomiasis, but the deposits have to be so heavy (of the order of 200 mg. DDT per sq. ft.), and are relatively so non-persistent under field conditions in the tropics, that it would be prohibitively expensive to apply them to areas of savannah woodland. Fortunately, promising results were obtained more cheaply with " space sprays ".

The number of applications, and the frequency with which they are made, are governed largely by the life-cycle of the fly, about which much is known (see for example Jackson, 1949). An adult female is fertilised soon after emergence, and a single larva develops within it. The larva is deposited when it is fully grown, and then burrows into the ground and pupates almost immediately. A female produces the first larva after a minimum period of 17 days, and subsequent single larvae at intervals of about 11 days, living long enough to produce approximately four larvae in all. The pupal period depends on temperature, and in East Africa is generally between 30 and 60 days.

If it is assumed for a moment that each application kills all adult flies, it is evident that the applications must be repeated at intervals of less than 17 days, to prevent larviposition by females that emerge between them, and it is also evident that the treatments must continue for a period long enough to ensure that adults have emerged from all the pupae formed before they began. A complete kill is not easily possible for a given application, at anyrate not at a reasonable cost, and in our work we have usually covered at least two average pupal periods by carrying out 6–8 applications at intervals of 14–17 days.

In each experiment, several square miles of woodland were treated. Oil solutions containing either DDT or BHC were applied as coarse aerosols with mass median diameters of 60–90 microns. The aerosols were produced either by running the solution into the exhaust of the aircraft engine, or by emitting it under pressure from fine nozzles fitted to a boom. Most of the applications were at nominal dosages of 0·2 lb. p, p′ DDT, or 0·03 lb. γ BHC, in 0·25 gals. per acre.

Drastic reductions in fly populations were usually achieved, although the results were poor in the two experiments in which BHC was used, the reduction being 90 per cent. in one case (Hocking, Parr, Yeo & Anstey, 1953), and only 50–60 per cent. in the other (Hocking, Burnett & Sell, 1954 *a*). These poor results were attributed not to an ineffectiveness of BHC at the dosages used, but to combinations of circumstances that led to relatively ineffective series of applications. DDT was used in the rest of our experiments. In one experiment, the kill of *G. morsitans* and *G. swynnertoni* was well over 99 per cent., and both species might well have been eliminated if there had been no immigration of flies into the treated area. In another experiment (Hocking, Yeo & Anstey, 1954), *G. pallidipes* seems to have been eradicated, since no flies of this species have been caught in very extensive searches over a period of three years; the reduction of *G. morsitans* was 98 per cent., and of *G. swynnertoni* only 94 per cent., although the population of the latter species has now fallen to less than 1 per cent. of the pre-treatment level. After an experiment against *G. swynnertoni* (Hocking, Burnett & Sell, 1954 *b*), no flies could be found for six months, and the species was almost certainly eradicated, only to be re-introduced when a large-scale movement of people brought flies into the area. In our last experiment, carried out in the Lango District of Uganda, treatment of 16 square miles of fly concentrations virtually eliminated *G. morsitans* and *G. pallidipes* from an area of 40 square miles. The initial population of *G. pallidipes* was admittedly very small, but none of this species has been found since the end of the applications, and catches of *G. morsitans* indicate a reduction of over 99·96 per cent. for this species and a residual population of less than one fly per sq. mile. It is in fact most probable that there is no stable residual population in this area; the very few flies that have been caught since the treatment have all been mature, and were very probably immigrants.

We have found it impossible to explain satisfactorily the finer differences in results in different areas. The poorest results have been associated with circumstances that would tend to reduce the effectiveness of the applications; for example, with adverse meteorological conditions that either resulted in poor applications or interfered with the cycle of applications. There is some evidence that the three species are not equally easy to kill under field conditions, and that increased leaf cover has reduced the effectiveness of the aerosols. But even when these and other points are taken into account, there seems to be some other factor that makes it difficult to predict the exact reduction that will be achieved; perhaps it consists of undetected, random combinations of all the factors that affect the applications. Except under very unfavourable circumstances, however, and provided that the risk of immigration is slight, our present technique can be expected to give reductions of at least 98 per cent., and the results are usually better than this.

Where the treated areas have been well isolated from neighbouring fly-infested woodland, the small residual populations have shown no tendency to rise during periods as long as 2–3 years, a fact of considerable interest and also of great potential importance. It is also interesting to note that random settlement and the introduction of livestock have taken place in some areas in spite of fly populations as high as 10 or more per sq. mile. On the other hand, serious outbreaks of trypanosomiasis do occur with population densities of this order and less. For a given proportionate reduction, the absolute level of a residual population is of course dependent upon the initial population level. Where there were originally 1,000–2,000 flies per sq. mile, not an unusually high density, a reduction of 99 per cent. would leave a population that would probably be still too high for settlement to be safe, whereas a similar reduction in a lightly infested area would reduce the population to such a low level that it would very probably disappear, or would not be a serious threat to settlement.

The cost of eight applications, based upon the expenses incurred during the period of the treatment, amounted to £1,000 per sq. mile, or 4*s*. per acre per application. Of this amount, approximately half arose from the operation and maintenance of the aircraft, and most of the rest was the cost of insecticides and solvents. These costs are rather high for tsetse control; they are less than for sheer clearing of woodland, but higher than for discriminative clearing or for methods based upon game eradication.

Of our other work with aircraft, an important result was obtained from a preliminary attempt to control *Simulium* spp. along the Nile at Jinja, Uganda, where these small flies are the vectors of onchocerciasis. Our technique, based on work by Wanson, Courtois & Lebied (1949), was to apply residual deposits of DDT to the vegetation growing along the banks of the river; in fact it was found that most of the control came from the larvicidal action of the insecticide that fell into the water. This led to a series of promising experiments by the staff of the Uganda Medical Department, who have, however, found ground methods to be cheaper. Promising results have been obtained in attempts to control a Coreid bug which is a serious pest of coconuts in East Africa; two applications, carried out in a very similar fashion to the tsetse work, gave a high measure of control for over two months. An outbreak of American bollworm (*Heliothis armigera*) upon a bean crop at Arusha was strikingly reduced by a single application, in an emulsion, of 0·36 lb. DDT per acre; the leaf growth upon the plants was abnormally light, however, and the result has to be confirmed. Attempts to control stalk-borer (*Busseola fusca*) in maize, using oil-bound suspensions and emulsions, have been less promising and gave only very partial control.

It is unlikely that aircraft will be used to control mosquitos and malaria in tropical Africa, except under special circumstances. They might be useful in urban areas to control the large increase in mosquito population that accompanies the onset of the rainy season. At Dar es Salaam, for example, this rise is almost certainly due to the enormous increase in breeding sites just outside the township, and might be checked by effective larvicidal applications from aircraft. We have made one such attempt, but the results were not spectacular. Granular insecticides might help in future work.

These experiments in the control of insect pests, and allied work with defoliants, raised problems connected with the production of various drop spectra and the effect of meteorological conditions and vegetation cover on the distribution of the insecticide; these are very involved and can be dealt with only in a general fashion in a paper of this sort.

The behaviour of large droplets, of a few hundred microns in diameter, is not greatly affected by atmospheric turbulence; apart from the short period during which they are caught up in the slipstream of the aircraft, their movement can be described adequately in terms of their terminal velocities and an appropriate wind speed. Such droplets impact readily upon obstacles of all sizes and do not penetrate dense vegetation, nor are they capable of reaching insects resting upon the undersides and leeward sides of obstacles. As the diameter falls below 100 microns or so, however, the droplets become more and more affected by the turbulent eddies in the atmosphere, and they are less efficiently collected by obstacles, particularly the larger ones. Very small droplets, of the order of a very few microns in diameter, behave rather like gas molecules; they remain airborne for very long periods and do not deposit appreciably.

When a " space spray " is applied to wooded areas, the insecticide must be in a form that will reach all, or nearly all, the resting sites of the insect that is being attacked, and it must therefore be able to by-pass the grosser obstacles, such as tree-trunks, branches and leaves, and yet still deposit upon the insect. Some theoretical considerations and small field experiments (Yeo, unpublished), and also experiments in a wind tunnel (Hadaway & Barlow, unpublished), showed that for tsetse flies living in savannah woodland the most suitable droplets had diameters in the range of about 10–50 microns; smaller droplets did not deposit efficiently upon the flies, and larger droplets were unable to reach sites screened by vegetation. In this respect the ideal spectrum for the tsetse work would probably have a mass median diameter of about 30 microns; so far we have not been able to produce such a spectrum with an apparatus that is suitable for field work, although we have produced a variety of droplet distributions of mass median diameters varying from a few hundred down to approximately 60 microns.

An empirical relationship has been established between the degree of atmospheric turbulence and the rate of deposition of a coarse aerosol of mass median diameter of approximately 80 microns. The measure of turbulence was basically the vertical gradient of air temperature divided by the square of the mean wind speed, and it was found (Yeo & Thompson, 1953, 1954; Yeo, 1954) that the dosages to be received by an insect were several times greater during the very stable conditions of large temperature increase with height and low wind speed than during unstable atmospheric conditions. Climatological surveys in East Africa (Thompson & Yeo, unpublished) have shown that these very stable conditions do not occur at all on certain days, and that the most effective applications are possible only during a short period of approximately one hour after dawn, and for a shorter, very variable period before dusk. In our tsetse work it was usually possible to carry out only one operation each day, and this had a considerable bearing upon the costs of control.

Some of our attempts to estimate the effect of a canopy upon the dosage distributions may be of interest. With large droplets, the results are as might have been expected; in densely canopied areas very few droplets reach the ground or the lower levels of vegetation, and where large dosages do occur they are almost invariably associated with gaps in the canopy. With smaller droplets, less then 100 microns or so in diameter, the effects are complex, as may be seen from the following example. A fine spray containing a defoliant was applied to a densely vegetated area, covered with thickets and trees so that at least 80 per cent. of the ground surface was obscured. Samples were taken from unshielded sites, and also from shielded sites within the canopy. It was found that for droplets greater than 100 microns the deposits in the shielded sites were about 15 per cent. of deposits in open sites, whereas for droplets 40 microns in diameter as many droplets were deposited in the shielded sites as in the open areas, and for droplets 10–20 microns in diameter the deposits in the shielded sites were 2–3 times the deposits in the open areas. Similar results were obtained from assessments of deposits in the crowns of coconut palms, in isolated thickets, and in savannah woodland.

To conclude, it may be said that although aircraft have not yet been proved to be an effective weapon for pest control in East Africa at a cost that is acceptable, there is sufficient evidence to warrant further work. For tsetse control, the future lies in obtaining more reliable and probably somewhat larger population reductions at a reduced cost; this might easily result with an improved drop spectrum, and with the use of more concentrated solutions so that, as was found in South Africa (du Toit, Kluge & Fiedler, 1952), reduced amounts of solution can be applied by smaller, less expensive aircraft. The control of the coconut Coreid is a problem for which aircraft have advantages over other methods of application, and it will almost certainly be possible to control other important agricultural pests. The prime need is for more basic and fundamental data upon which an adequate programme of work can be planned; aircraft are expensive to maintain, and only by obtaining high rates of utilisation from them can costs be brought low enough for the poor and relatively undeveloped countries of Africa.

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Recent Developments in the Use of Insecticides from Aircraft against Locusts

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Dr. Gunn, who introduced this subject at the 1948 Conference (1), pointed out that the useful results he had recently recorded in Tanganyika were obtained against settled locusts and in circumstances that, in his experience (and in ours), were unusually favourable for the spraying technique used. He accordingly considered that suitable ground machinery might well have been cheaper and equally effective against settled swarms in such circumstances, and directed attention to the particular need for the development of aircraft methods of attacking swarms in flight independently of ground parties (2). Recent trials in India, carried out in co-operation with the American Point 4 Technical Assistance administration, have further emphasised the inevitable limitations of techniques of aircraft operation dependent on ground parties for scouting and demarcation, whether against swarms or hoppers (3). Our own aircraft work in recent years has accordingly been very largely concerned with the development of methods of dealing with flying swarms, though before passing to this I mention that promising results have recently been obtained by Milnes with dieldrin on egg-fields in Tanganyika, and that the experience of the French locust control organisation in Madagascar shows that the difficulties (though not the expense) of operating and maintaining helicopters in the field under tropical conditions are less than had formerly been believed.

In 1952, the developing plague of the desert locust (*Schistocerca gregaria*) made possible the resumption of airspray trials in Kenya, financed from Colonial Development and Welfare funds. The first complication was that though the swarms concerned were found to travel directly down-wind, their ground-speed was consistently less than the speed of the wind, as a result of the intermittent nature of the flight of the individual locusts. Now the "aerial curtain" technique as originally suggested involved successive spray-runs between fixed air-positions across the heading of the locusts (4). This was clearly inapplicable under our conditions, since spray applied in this manner would move away from the swarm instead of into it. Fortunately this type of swarm behaviour (movement down-wind at a ground-speed less than the wind-speed) had been encountered and studied during a series of preliminary aircraft observations in 1951, and it had been decided that such swarms should be attacked by drift-spraying, using the flying locusts for demarcation, but treating the temporarily settled locusts beneath, which probably represent the greater part of such swarms, as the primary target.

Positive results were in fact obtained (5); a swarm of 300–400 acres was for example almost completely destroyed by 340 gals. 20 per cent. DNC. The detailed analysis of the data, however, made it clear that something approaching the right answer had been obtained for a combination of wrong reasons. Thus from the emission-rate and drop-spectrum used (determined for us by the Colonial Insecticide Research Unit at Arusha), and the wind and spraying-height recorded during particular operations, it could be shown that the dosage of spray reaching the ground must have been quite inadequate to deal with the settled locusts, which had been regarded as the primary target. On the other hand, by using the latest laboratory data of Wootten & Sawyer on the toxicity of DNC to flying locusts (6), and the illuminating method of graphical analysis developed by Sawyer (7), it was possible to show that the size of the kill actually obtained was in fact of the order to be expected from the recorded density of the flying locusts that had been sprayed under these conditions.

The graphical analysis not only showed that the primary target should be the flying locusts and not the settled component of the swarm but it also showed that, for this purpose, the spraying heights used had been too low, probably by several hundred feet, and the spray had been too coarse. As regards the last point, the analysis attributes 80 per cent. of the kill to drops smaller than 100 microns, which comprised less than 30 per cent. of the total volume of this particular spray.

Further trials, financed by Desert Locust Control, were accordingly undertaken in the following season, using a drop-spectrum with a mass median diameter of 140–150 microns instead of 220 microns, and tactics directed against the flying locusts instead of the settled ones; and the results confirmed and extended those of the previous seasons.

Later in 1953, four Auster spraying aircraft were made available by the Food and Agriculture Organization of the United Nations for further work on these lines. The aircraft were first flown to the Sudan in May–June to assist in similar operations planned by the Sudan Government. Flying locusts were found by aircraft on some 70 occasions in the course of 310 hours' air reconnaissance, but apart from thin swarms sprayed in Kordofan in late July by Sudan aircraft, were found only at densities of the order of 0·0001 per cubic metre—too low to present economic spray targets.

After a few operations during June–July against mature flying swarms during the rains in the Eritrean highlands, on a scale limited by weather, the aircraft were transferred to the Somaliland Protectorate in August. In operations against young swarms just moving out of a temporarily uncontrolled breeding area in eastern Ethiopia, evidence was obtained to suggest that the locusts were more susceptible to spraying at this stage than later in their adult life; a similar finding had previously been recorded in Pakistan (8).

In operations against swarms escaping from the very heavy breeding in the Somali peninsula late in 1953, the four FAO aircraft were supplemented by five other Austers and, for shorter periods, by a Rapide and an Anson; data were thus provided on the comparative economics of representative single-engined and twin-engined aircraft and of chartering as opposed to direct operation. Air reconnaissance over Somalia, undertaken with the co-operation of the Italian Trusteeship Administration, located the leading swarms as they reached the Juba river. Operating from ten successive bases extending for over 600 miles across Kenya and Tanganyika, the unit remained in continuous contact with the incoming swarms for nearly three months, until well after the beginning of breeding. Spraying began as the first swarms entered Kenya, and took place on all save eight days of the following nine weeks. A total of 162 tons of concentrated insecticide (31,400 gals. 20 per cent. DNC and 4,300 gals. 11 per cent. γ BHC in oil) was applied in 724 sorties, totalling 960 flying hours. Target swarms were located, as in each of the two preceding years, entirely by air reconnaissance, which accounted for another 700 hours, in addition to 380 hours of ferrying and 40 hours of test and miscellaneous flying.

The invasion was the heaviest experienced in East Africa since the height of the last outbreak, with individual swarms up to 100 square miles in extent, as compared with target swarms of less than a square mile in each of the preceding seasons. Its scale proved to be well beyond the resources of the unit and, of a total of some 35 swarms attacked, no more than half a dozen can be claimed as probably completely destroyed. Two large-scale field assessments, however, and one on a smaller scale, all made under conditions representative of the season's operations, agreed in giving kills of about 300 thousand locusts per gallon of insecticide—approaching a ton per gallon—which may be compared with the corresponding figures of 5–7 thousand locusts per gallon given by the best-documented kills of settled locusts so far available (9). Ten years ago Kennedy and Toms drew attention to the potentially promising nature of the target presented by a flying swarm; and subsequent laboratory data (6,10) indicated that flying locusts are something like 50 times as susceptible to spraying as settled ones (5). Our assessments provide evidence that this promise may in fact be realised in the field; and the greatly enhanced susceptibility associated with flight may perhaps prove to be of interest in the study of insecticidal action in general.

It is, however, instructive and salutary to compare what has so far been done, with the size of the problem involved. The aircraft reconnaissance and ground assessment data available this season, together with corresponding photographic records of the density and behaviour of flying locusts secured by a research party led by Miss Waloff, not only provide the first evidence of the actual number and size of the invading swarms, but also make possible an estimate of the order of magnitude of the locust numbers involved. The aircraft recorded some 50 swarms entering Kenya during January, with a total area of about 500 square miles, and this represented certainly most, but probably not all, of the invasion. The ground assessment of a complete kill, together with photographic data, suggest 30 locusts per square yard of plan area of these swarms as a representative figure for area density under these conditions. This gives a total of the order of 50,000 million invading locusts—perhaps 100,000 tons. Comparison of this figure with the efficiencies given by our field assessments indicates that the aircraft are unlikely to have accounted for more than perhaps a quarter of the incoming locusts. Fortunately, laboratory data, which have provided such useful guidance in the development of the method, also indicate possibilities, particularly of still finer sprays, in obtaining field efficiencies substantially higher than we have so far recorded, and we clearly need them.

Field data obtained by Ashall and Miss Ellis on the marching density of hopper bands in the Ogaden, representative of those that produced these swarms, indicate that an invasion of this size would have been derived from about 1,000 square miles of fifth instar hoppers, corresponding to about 150,000 of the largest bands studied. Some 180,000 bands of all sizes were in fact destroyed on the ground by baiting in Somaliland and eastern Ethiopia alone during November and December 1953, which provides some indication of what East Africa might have experienced in the absence of such control operations.

Our biggest aircraft effort so far has thus fallen well short of being able to deal with a major invasion at the height of an outbreak. Two months ago, however, we received a request for help from the International Red Locust Service, which provided experience of the assistance that aircraft might afford at an earlier stage in the development of an outbreak. A small swarm of red locusts (*Nomadacris septemfasciata*) had escaped from the grass plains of the Rukwa Valley in Tanganyika, which constitute a major outbreak area of this species, into the surrounding forest, in which no effective control by ground machinery was possible. While the swarm was very small by current desert-locust standards, only 100–200 acres, such an initial escape from the outbreak area was considered a potentially serious matter for the surrounding territories. The first aircraft reached the Rukwa on the day after the original signal was received in Nairobi, and two days later, as soon in fact as the necessary aviation petrol arrived, the swarm was destroyed in flight in four sorties by two Austers, operating with the help of a ground party provided by the Red Locust Control Service.

Finally, a little about costs. The three months' air campaign against the desert locust at the beginning of this year cost £70,000 in all, of which insecticides, ground expenses and flying costs each accounted for about a third. The locally-chartered twin-engined aircraft were more economical than the chartered single-engined machines, but roughly comparable in this respect with the directly-operated single-engined aircraft. The total cost corresponds to £2 per gallon of insecticide applied, equivalent in turn, from the ground assessment figures, to about £6 per million locusts killed. No completely comparable figure is available for the cost of routine control operations on the ground, but, from some recent assessments by Ashall of potential baiting efficiency in the field, it is possible to estimate the cost of baiting a comparable number of locusts in the third instar (the middle of the hopper stage) under optimum Somali peninsula conditions. Kills of 2,000 to 7,000 third-instar hoppers per 100 gm. bran bait containing 0·1 per cent. γ BHC were recorded, in circumstances in which the whole of the bait applied was consumed. This corresponds to a kill of 16 to 60 million third-instar hoppers per ton of standard bait. During the campaign of November-December, 1953 some 2,500 tons of bait was applied in Ethiopia and the Somalilands, at a total cost of £175,000, or £70 per ton. From Ashall's figures, this corresponds to £1–4 per million locusts killed as third-instar hoppers, compared with £6 per million for killing them by aircraft when they had reached the adult stage. Now the bait assessments were carried out in above-average conditions, in that no bait was wasted. Furthermore, at times when locust populations are increasing, which is when control is most important, any such comparison between methods attacking different parts of the life-cycle is necessarily biased in favour of the method envisaged as being tried first. In this respect, the present comparison is therefore biased in favour of hopper control. It would accordingly appear that, even at the efficiencies attained this season, aircraft spraying of adults is at least not seriously more expensive than baiting the corresponding hoppers and, as already mentioned, these levels of spraying efficiency leave scope for very considerable improvement. Furthermore, the scale of the ground operations in the Somalilands and Ethiopia, though not sufficient to prevent serious escapes, was not far short of the limits imposed by the communications and general administration of the operational areas. In conclusion, I would suggest that aircraft operations against flying swarms are to be considered not in competition with operations against hoppers but as a complementary method of control, making possible for the first time a sustained attack upon locusts throughout their life-cycle, and perhaps offering particular promise as a means of dealing with the early stages of a developing outbreak.

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Discussion

Dr. W. F. Jepson asked whether destruction of 98 per cent. of the tsetse population in an African savannah area, combined with social and administrative measures to settle the area with a unit of population that would help to keep down the low tsetse population, would be sufficient for practical control.

Mr. Yeo replied that in the area in Tanganyika in which he worked, 98–99 per cent. control left 10–20 tsetses per sq. mile and this might possibly be enough for trypanosomiasis transmission. In lightly infested areas, 99 per cent. control might reduce the population to 1 per sq. mile, and with such a low density the fly might die out. He thought, however, that Dr. Jackson might be better able to give information on this subject.

Dr. C. H. N. Jackson said that the density of tsetse flies varied considerably, so that 98 per cent. reduction had different results from place to place, but a reduction of that order would allow infiltration of Africans and their cattle into the area. The country would be so altered by trampling, grazing and wood-cutting that it would become intolerable to the remaining flies. He referred to a game-destruction experiment in which cattle entered the area in the fifth season owing to very dry conditions. Some tsetse flies were still present but their numbers did not increase. One great value of insecticidal experiments was that they make it possible to reduce fly populations without altering the ecological conditions, as other control methods necessarily did, and it was therefore of much interest that fly populations did not increase after they had been reduced by insecticides or other measures. This agreed with an idea common among some workers for 20 years that tsetse flies do not compete with one another either for food or shelter, suggesting that absolute densities are not fixed and may be permanently altered by control measures without any change in the habitat. It is encouraging for control measures, because a heavy but incomplete reduction of flies, unless there is mass reinvasion from elsewhere, may leave an area available for utilisation more or less at leisure.

Mr. W. H. Potts asked if there were any figures showing at how low a density the tsetse population could maintain itself indefinitely. Commenting on Dr. Jackson's picture of people and cattle driving out tsetse flies he recalled that the reverse often occurred. It would be of biological interest and practical importance to know at what levels of populations one or other state of affairs came about.

Dr. F. L. Vanderplank suggested that the maintenance of a tsetse population at a reduced level after the application of an insecticide might be due to some considerable alteration by the insecticide of the composition of the ant population. In experiments against a Coreid bug on coconut in Zanzibar, even one application of DDT considerably altered the ant population, killing small species and rather encouraging large ones.

Dr. R. S. Scorer referred to Mr. Yeo's statement that conditions were suitable for applying insecticides from aircraft for only about two hours of daylight, and enquired into the possibility of night flying, possibly with the use of searchlights. Mr. Yeo replied that it was necessary to fly at only about 15 ft. above the canopy and this would be impossible in the dark. Dr. Scorer suggested that the meteorological conditions at night were so much more suitable that it might be possible to spray effectively from a much greater height. Mr. Yeo replied that conditions at night were not suitable in Tanganyika. The air was not stable and calm, as there were lapse conditions and strong winds. Moreover, high flying resulted in a low dosage being applied over a wide area, and this was less satisfactory than a higher dosage over a smaller area.

Dr. T. A. M. Nash asked whether the season at which spraying was done was important. It was possible that spraying in the wet season, the season of natural fly increase, would prove more effective in the long run, because the small population remaining might be wiped out by the adverse conditions of the dry season. Mr. Yeo replied that this might be biologically true, but it was not practicable, at any rate in East Africa, to operate in the wet season.

Dr. W. E. Ripper referred to experience in the spraying of crops in the Sudan and elsewhere, and said that helicopters could be used in the wet season if it were biologically desirable, and might possibly be used at night. The pilot was happier in a helicopter than in an aeroplane once it was in the air.

Mr. Yeo said that helicopters could not operate in East Africa at a cost of 2*s.* per acre, the present cost with aeroplanes, and this was still too high. He explained that the measurements of population density on which their estimates of reductions were based had been made by using marked flies according to the technique evolved by Dr. Jackson. Referring further to the critical level for persistence of tsetse populations, he said that *Glossina morsitans* survives quite well at a population of 5–10 per sq. mile. In the case of *G. pallidipes* some flies were caught six months after an insecticide application but the population then died out. *G. palpalis,* however, may be able to recover from very low densities, for although in some cases it had apparently been eliminated on islands in Lake Victoria, its numbers had returned to normal after a few years. It is not certain, however, that this was not due to immigration.

DISCUSSION ON THE EFFECT OF THE USE OF CHEMICALS ON THE BALANCE OF ANIMAL POPULATIONS

Chairman: Mr. A. D. Pickett,
Division of Entomology, Department of Agriculture, Canada

The Chairman said that his mind had been ranging back over thirty years of professional work. At the beginning of that time he had tried to teach people how to use insecticides, and he was now having to go back and tell them that his recommendations had been wrong. This discussion should explain why, and it would be opened by the reading of a paper by Dr. Massee, who had had long experience in the spraying of deciduous fruit trees at East Malling and was much interested in the problem of the effects of the sprays on the insect populations of the orchards.

Problems arising from the Use of Insecticides: Effect on the Balance of Animal Populations

By A. M. Massee
East Malling Research Station

The disturbance of animal populations by chemicals presents no new problem, and this phenomenon was noted in apple orchards in this country some 25 years ago (Massee & Steer, 1929). Many factors influence the size and composition of animal populations; indeed the subject is so vast that it will not be possible to survey the whole field. Instead, examples will be given of the fluctuations of animal populations of the fruit orchard, with special reference to the effect of chemicals upon the fruit tree red spider mite (*Metatetranychus ulmi*), the apple capsid bug (*Plesiocoris rugicollis*), the red spider mite (*Tetranychus urticae*) and the woolly aphis (*Eriosoma lanigerum*).

Numerous factors are associated with the fluctuations and composition of the orchard fauna, and it is not until the problem is studied in detail that the complexity of the subject is appreciated. Not only do the insects fluctuate in numbers from year to year, but their relative importance changes also; new pest species increase in importance from time to time, while some of the more familiar species fade into the background or become quite unimportant. The reasons for these changes have not been ascertained, but the use of new chemicals in the pest control programme is one of the many factors at work.

The Fruit Tree Red Spider Mite

To enable the rôle of the fruit tree red spider mite and its status in relation to the chemical control of fruit pests to be appreciated, it will be essential to discuss the story of the mite since it was first observed on fruit nearly fifty years ago.

The first record of its occurrence on cultivated fruit appears to be that of Theobald (1905). In a short note in the Wye Journal, he refers to a beneficial red spider on fruit, then known as *Tenuipalpus glaber*, and states that the specimens were received from Ross on 18th March 1905. The account says " the eggs frequently coat the twigs and smaller stems in a dense mass " and continues " as far as personal observations go, they seem to be beneficial, feeding like the Beetle Mites on green matter, fungi, lichen, etc., especially the green algae we so frequently see on the trees ". The next record of the mite is also by Theobald (1909). Although the fruit tree red spider mite is not actually mentioned by name in his notable work on the insect pests of fruit, two photographs of its egg masses appear on page 403. They are mistakenly referred to, however, as the egg stage of the beetle mite. Many years later, Theobald informed me verbally that both of these early records in fact referred to the fruit tree red spider mite.

Although this mite occurred in small numbers in many commercial orchards in the South-east of England, it was not recorded again until Massee (1926) stated that it was beginning to increase very considerably on apple. Its populations were first seen to increase in commercial orchards in 1923, and that year saw the beginning of the very significant changes that were to follow.

Until 1922, the customary spray programme was very simple, more than one spray application being seldom made to any given orchard, and probably more significant the total acreage washed was very small. In 1922, however, the tar-oil washes were first used commercially in apple orchards of England, and it is an accepted fact that from this year onward a general increase of mite populations occurred in most of the orchards in which these new winter washes were used.

Various theories have been advanced to explain this marked increase of the mite after the application of the tar-oil washes. The following explanation seems to be the correct one, and is based upon observations in the field. It was found that the tar-oil washes (which in those days contained the tar acids) were not toxic to the winter eggs of the mite, but at the same time had a marked toxic effect upon many species of insects that hibernate on the tree. Amongst these were beneficial species, including the Anthocorid bugs, the ladybird beetles, and minute predacious mites. Many of the species were known to be predacious upon all active stages of the fruit tree red spider mite and its eggs (Massee & Steer, 1929). In addition, the tar-oil washes destroyed the foreign growths, such as the mosses, lichens and algae growing on the stems and branches, and the loose bark peeled off the tree trunks. This in effect removed the overwintering quarters of many beneficial species that might otherwise have survived the winter wash. The destruction or disappearance of the beneficial insects from the orchards largely accounted for the rapid build-up of mite populations in the spring, after their emergence from the winter eggs.

There was a continued upward trend of mite populations in commercial orchards during the years from 1930 to 1940, particularly in Essex, and the mite was regarded as a major pest of apple, plum and damson on many fruit farms. In fact its prevalence led to a modification of the spray programme by the introduction of the petroleum and DNC-petroleum washes, which were used primarily against its winter eggs. In spite of these new winter ovicides, however, the problem of adequate mite control became increasingly urgent.

The situation became even more acute as a result of the introduction of DDT and BHC into the spray programme in the years 1946–48, when pronounced changes in the orchard fauna were noted. At this time over 40 species of beneficial insects were known to occur on apple (Collyer, 1949) and most of these species were found to be killed by DDT and BHC. It was therefore suggested that these insecticides should not be used later than the green cluster stage of bud development, except in special circumstances, to prevent the destruction of the beneficial species. Fortunately most fruit growers have accepted this recommendation, and DDT is rarely used after the blossom period. At the same time, populations of the mite were becoming even greater in commercial orchards, particularly those in Essex, and fundamental researches on its life-cycle and control were greatly intensified.

In addition to the depression of beneficial insect populations following DDT or BHC sprays, it is stated by Hueck & others (1952) that an increase of egg production follows the application of low DDT concentrations. It is claimed that the DDT stimulates the adult female mites just prior to oviposition.

The organophosphorus acaricides were added to the spray programme in 1950, and, unlikely as it may seem, even greater mite populations built up in commercial orchards in which they were used. Parathion was used by many fruit-growers, two applications being applied at the fruitlet stage. This spray proved effective against the adult and immature mites but was not toxic to the eggs. The sprays effected a considerable initial reduction of mite populations, but later in the season a big increase of mites followed, and the winter egg density was very considerable. All the predacious insects present on the trees were killed following the application of the organophosphorus sprays and, once the residual effect of these potent sprays had worn off, the mite build-up was very rapid (Collyer, 1953 *a*).

During the past two years three new summer ovicides have been used experimentally and commercially against the mite. These are p-chlorophenyl benzene-sulphonate, p-chlorophenyl p-chlorobenzene sulphonate and p-chlorobenzyl p-chlorophenyl sulphide. They are proving very successful, and it seems likely that they will supersede all the acaricides formerly used. The evidence so far available suggests that they have the additional advantage of being comparatively harmless to beneficial insects and mites.

The fact that efficient summer ovicides are available against the mite is very encouraging, but even at this early stage, and before their true value can be assessed over a number of years in the field, suggestions are being made to include DDT in the spray programme in July to control the codling moth. Surely this suggestion is contrary to the best interests of the grower, and the addition of further chemicals to the recognised spray schedule should not be made until the proposed changes have been tested experimentally and their true value proven.

The Apple Capsid Bug

The interesting story of the apple capsid bug and its gradual influx into commercial orchards, followed by its equally sudden disappearance some 30 years later, forms part of the complex of the effect of chemicals on the balance of animal populations.

The natural host plants of this Mirid are willows (*Salix* spp.) and bog myrtle (*Myrica gale*), but in 1911 it was noted feeding on apple foliage at Wisbech. It spread rapidly in commercial apple plantations, and soon became established in all commercial apple growing districts of England, with the exception of the greater part of Essex and a limited area of Kent. It caused very severe injury to the fruitlets, and before long was regarded as one of the most important fruit insects. The introduction of the winter petroleum wash into the spray programme in 1930 was made with the object of killing its overwintering eggs and those of the fruit tree red spider mite. However, in spite of the petroleum wash and numerous other recommendations, the bug continued to flourish as a major pest until DDT was added to the routine spray programme in 1946. The DDT proved very efficacious against the immature forms of the bug, and it disappeared from the commercial orchard as quickly as it arrived.

The establishment of the bug in commercial orchards, and the rapid build-up in its new environment is not understood, and it is suggested that the complex spray programme usually adopted after the first world war may have been largely responsible. Here it may be noted that the bug has never established itself in unsprayed orchards. It is also certain that the DDT spray, which was first added to spray programme in 1946, accounted for its rapid disappearance from sprayed orchards.

The Red Spider Mite

The fruit tree red spider mite (*Metatetranychus ulmi*) has long been regarded as the only mite of economic importance on apple in this country, but, a second species, known as the red spider mite (*Tetranychus urticae*), has been noted in several Essex orchards since 1949, and its populations have reached alarming proportions on some occasions. It is generally accepted that *M. ulmi* causes more harm to orchards in Essex than elsewhere in England, and in consequence the fruit growers of that county are prepared to make several spray applications in an endeavour to keep the mite populations as low as possible. To achieve this end, a number of growers have been making several applications of parathion to their trees. Now, in some of the orchards where three, four or even five applications of this compound have been used, there follows a very substantial increase of *T. urticae* (Collyer, 1953 *b*). This phenomenon is not confined to apple, since equally large populations of the same mite have been noted on black currant in early July, following only one application of DDT or parathion earlier in the year.

The Woolly Aphis

The woolly aphis, formerly a troublesome pest of apple in many orchards, has become relatively less common in most seasons, following the introduction of its parasite (*Aphelinus mali*). The value of the parasite as an additional means of controlling the aphis is accepted, but it is most efficacious in seasons suitable for the early emergence of the adults, when strong colonies are built up during the summer months. In late seasons, it does not build up sufficiently early to check the woolly aphis until late autumn, by which time much injury has been caused to the tree. In orchards in which DDT is used later than the green cluster stage pre-blossom, or after petal-fall, the woolly aphis tends to increase rapidly and infestations may be severe. This population build up is considered to be correlated with the suppression of the parasite by the DDT spray. In America, an increase of woolly aphis has been reported following the use of DDT (Newcomer & others, 1946) and the increase is considered to be due to the eradication of the parasite. Yothers (1947) states that where DDT is used to control codling moth in the Pacific North West, the woolly aphis threatens to become a destructive pest, requiring the applications of sprays for its control.

Conclusions

As mentioned earlier, many factors contribute to the fluctuations of the orchard fauna, for not only do its members fluctuate from season to season, but their relative importance changes also. Still more important is the arrival of new pests from time to time, while some well-established species become of very minor importance owing to modifications of the spray programme.

Fifty years ago, 70 to 80 insects were regarded as potential pests of our orchards, but most of these species no longer survive in commercial plantations where new sprays and modern equipment are used. Nevertheless, the four pests that still persist to-day may prove just as troublesome as the far greater variety present at the beginning of the century.

The risk of introducing new chemicals or increased concentrations of accepted insecticides or acaricides into the spray programme without their being tested over an adequate period needs no further emphasis, but even today their introduction continues unabated. Owing to the high cost and shortage of labour, the high price of insecticides and fungicides, and the need to apply the sprays quickly, the grower is attracted to the mobile machines and the medium and low volume spraying equipment. The latter machines are designed to apply a volume of 50 gallons an acre or even less, while the concentration of the insecticide is many times as great as that normally used in the hydraulic machines. It will obviously take very many years before the overall effects of these highly concentrated chemicals can be assessed in the field, and their general effect on the balance of animal populations can be ascertained. The low volume machines are being used more and more in commercial orchards each year, and it will be interesting to watch the effect on the balance of insect populations of their introduction into the pest control programme.

The results of our work at East Malling led us to make a study of the ecology of the insects of our fruit orchards. The specific aim of our work is to put the spraying of fruit on a scientific basis and to modify spray programmes so as to preserve beneficial insects and not destroy them. The lessons of the past few years underline the need of a detailed ecological study of the orchard fauna, rather than research into the life-history and control of selected species. While the latter has been the fashion in the past, the former should be the future goal of entomologists of all countries. Such an approach would enable spray programmes of an arbitrary nature to be abandoned, and allow new programmes to be developed upon a sound and wide knowledge of their biological interactions. In order to achieve this ideal, it will be imperative for the spray chemist to work in complete collaboration with the entomologist, for him to modify his outlook on pest control, and also for him to abandon the search for highly toxic insecticides in favour of a search for highly selective insecticides and fungicides. If he does, we may hope that the new sprays may be relatively innocuous to at least some of the beneficial insects and mites of our orchards.

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Discussion

Dr. D. S. Maclagan said that comparatively little was known about the effects of the new synthetic insecticides on the fauna of the soil, and, in view of the heterogeneous assemblage of animals there, in a relatively stable environment, he had suggested to one of his assistants (J. G. Sheals) that the addition of BHC and DDT to old pasture land might produce interesting results from an academic viewpoint, in addition to any features of economic interest that might be revealed.

Accordingly, replicated plots were treated with BHC and DDT alone and in combination, and samples then taken at intervals. The census of Collembola after seven months was of special interest. The Collembolan population showed statistically significant decrease in the plots treated with BHC and a significant increase in the plots treated with DDT. The population in plots treated with both insecticides did not differ significantly from that of the control.

Phenomena of this kind could be explained by bio-mathematical theories of predator-prey interaction, and the results of the investigation could be interpreted on the assumption that the predators concerned were more susceptible to DDT but less susceptible to BHC than the Collembola. The increase of the latter would then be directly due to the destruction of predators by DDT, and the decrease to the toxic effect of BHC to the Collembola. The fact that the population in the plots receiving both insecticides was higher than that in the plots receiving BHC alone would then be attributable to the additional toxicity of DDT to the predator population, which placed the residual Collembolan population at an advantage for numerical increase.

Far the most important of the predators involved proved to be mites of the families Gamasidae and Rhodacaridae. Preliminary toxicity tests indicated that these mites were less susceptible to BHC than Collembola of the arthropleon group and that the latter are extremely resistant to DDT. The non-sensitivity of arthropleon Collembola to DDT was perhaps due to their lack of sensillae, and might be viewed as an argument in support of the contention that these creatures are not insects.

Dr. F. L. VANDERPLANK illustrated the selective action of insecticides by experience in Zanzibar with the Coreid that caused excessive nutfall of coconuts. Mr. Way showed that it could be controlled on a small plot by dusting with BHC but the palms then became smothered with scale and Aphids. He (Vanderplank) found that both DDT and BHC dusts and other formulations caused similar harmful effects. When, however, a special oil formulation of DDT plus coumarone resin was used, it was found that this formulation, atomised in an air-blast to a droplet size of about 60 microns, had a very marked selective action. It reduced and even eradicated harmful ants of the genera *Pheidole*, *Anoplolepis* and *Crematogaster*, but did not injure the beneficial ant, *Oecophylla* sp., which increased from nil to 37 per cent. (reckoned by the number of palms colonised) in some sprayed areas. It did not harm the predators and parasites of scale and Aphids, and these pests did not increase.

Mr. I. F. B. COMMON said that the woolly apple aphis (*Eriosoma lanigerum*), which had been controlled for some years in Australia by the introduced parasite, *Aphelinus mali*, had resumed its position as a pest there following the use of DDT to control the codling moth (*Cydia pomonella*). He asked whether any work was in progress in the Commonwealth on the resistance of parasites and predators to such insecticides.

Mr. A. B. BAIRD replied that *Macrocentrus ancylivorus*, a parasite of the oriental fruit moth, had been used in research carried out at the Belleville Parasite Laboratory in Canada to determine whether parasites develop resistance to DDT, and that the results so far obtained had shown that resistance or tolerance could be built up in it.

Dr. E. S. NARAYANAN said that the Fulgoroid, *Pyrilla perpusilla*, was one of the serious pests of sugar-cane in India, but that its outbreaks used to occur cyclically at intervals of some 5–7 years. It was largely controlled in the intervening periods by a succession of parasites that attacked the eggs, nymphs and adults. Epidemic outbreaks had, however, become continuous since the use of the recently discovered organic insecticides had become widespread, evidently because the parasites were destroyed by them. Their use had now been discontinued.

Dr. J. R. BUSVINE said that when an insecticide had reduced a pest population, the balance of nature swung back after the effects of the insecticide had ceased; sometimes, as Dr. Massee had shown, it swung past the original position owing to selective destruction of parasites. It might, however, be encouraging to recall two cases in which the population remained depressed even when the pressure of the insecticide was removed. One, cited at the preceding meeting, was that of the tsetse populations that remained low for two years after air spraying. The other was the situation in Sardinia, where DDT had been used for several years in an attempt to eradicate the malaria vector, *Anopheles labranchiae*. It was not eradicated, but its population was greatly reduced. Two years later the entomologists Trapido and Aitken expected to find that it had regained its former numbers. Instead they found that it was still rare and that its place seemed to be filled by *A. hispaniola*, a mosquito that is not dangerous and had previously been exceedingly scarce.

Dr. T. H. C. TAYLOR pointed out that the crux of the problem was the yield of the crop, and considered that it would be wrong to advocate measures designed to favour natural enemies without proof that the measures advocated would give a better yield and be more satisfactory from an economic point of view than the use of insecticides without regard to natural enemies.

Dr. W. E. RIPPER pointed out that there were selective insecticides that complemented the control afforded by natural enemies. An example was provided by experience in the control of the black fly (*Aphis fabae*) on sugar-beet in England. The Aphids were attacked by Coccinellids and both were almost eliminated if parathion was used for Aphid control. If the weather was warm, the few surviving Aphids multiplied rapidly and the plot became severely infested. If, however, a systemic insecticide such as schradan was used, the Aphids were killed and the Coccinellids were not. The crop remained free from infestation and the Coccinellids also migrated to neighbouring unsprayed plots and killed the Aphids there.

The CHAIRMAN said that better and cleaner crops could sometimes be obtained by reducing the spray programme. Serious infestations of apple by the mussel scale developed in Nova Scotia in and after 1935 as a result of the extensive use of elemental sulphur fungicides against apple scab that began about five years before. The scale was almost eliminated after the application of sulphur and winter washes was discontinued. Other pests involved in modification of the spray programme were red spiders, the eye-spotted bud moth and the codling moth. Mineral oils, tar oil and dinitro compounds had now been eliminated from the programme, and lead arsenate and sulphur almost eliminated. Only one or two applications were made in the year, as compared with 6–8 ten years ago. The materials selected were those that did not interfere with beneficial insects, and the spray costs were halved.

Prof. G. C. VARLEY said that basic research was needed to determine what factors prevented pest populations from reaching levels of economic importance. Until they were known, it was impossible to judge the effect of insecticides. They might be specific parasites, general predators or lack of food. If an insecticide could be applied cheaply and could reduce the pest population to a greater extent than natural increase could replace, its application might be justified, though it might have to be continued indefinitely, possibly until the pest became resistant. If the insecticide was ineffective or reinfestation was easy, and especially if the pest had a short life-cycle, the situation might rapidly get out of hand. Insecticides certainly had a place against pests not controlled by natural enemies, as exemplified by their use against wireworms.

Dr. MASSEE agreed with Dr. Taylor that it was necessary to ascertain the true value of natural enemies, and said that this was the object of the investigation on the predators of the red spider at East Malling. At least 80 species were already known to be associated with it and there were almost certainly many more. It was thought a few years ago that the principal one was the Capsid, *Blepharidopterus angulatus*, but it now appeared that Typhlodromid mites were much more important. It was well worth while modifying the spray programme so that natural enemies could keep populations down.

The CHAIRMAN said that if the case for beneficial insects was not proven, the case for insecticides was not proven also.

DISCUSSION ON THE DEVELOPMENT OF RESISTANCE TO INSECTICIDES

Chairman: Professor V. B. Wigglesworth, C.B.E., F.R.S.,
Department of Zoology, Cambridge University

The CHAIRMAN said that it was a tragedy that the finding of effective insecticides had been followed by the development of resistance to them in insects, so that action and reaction were equal. He called on Dr. Busvine to read the opening paper.

The Development of Resistance to Insecticides

By J. R. Busvine
London School of Hygiene and Tropical Medicine

It is rather important to have a clear conception of what is meant by the term " insecticide-resistance ", because the word resistance has been used in two rather different senses. Until recent years, the majority of entomologists concerned with insecticides used the word to denote a *normal* character of a particular insect or species. I myself included a definition in this sense in a chapter on insecticides for a book written some six years ago. But there is also another usage, which has become more widespread lately, to denote an *abnormal* character of individuals or strains of certain species, usually prevalent through selective mortality due to insecticides. Not infrequently, confusion arises, especially in confusing normally resistant species and abnormally resistant strains. So far as this talk is concerned, I propose to use the word in the new sense and refer to " resistance " in the old sense by means of its converse, susceptibility.

In reviewing the subject of insecticide resistance, it is a common practice to point out that this is not a new phenomenon and to cite a series of instances, beginning with the resistant scale insects of some 40 or 50 years ago. However, when we look into this list more closely and examine the original papers, we find a very heterogeneous collection, since it includes field and laboratory observations, some of them ambiguous cases described in a single publication, others extensively investigated and well documented. Proving the existence of a resistant strain and defining its characteristics requires careful experimental work. Failure of insecticides in the field after successful control, is no more than *a priori* evidence of resistance. We all know the failure of insecticides in the field may be due to many causes, such as variations in environment, faults in the insecticide or its application, or selective destruction of parasites. Even if an abnormal strain of a pest becomes dominant, it may be escaping the insecticide by reason of different habits rather than abnormal resistance. For example, it appears that the so-called arsenic-resistant strain of the codling moth is normally susceptible to doses of arsenic fed to it (14) or injected into its body cavity (15). In the field, it escapes destruction by being more successful in burrowing into apples sprayed with lead arsenate or other chemicals or, indeed, into unsprayed fruit (17).

Again, there is evidence to show that strains of the mosquito, *Anopheles albimanus*, while remaining normally susceptible, have become hypersensitive to irritation by DDT and thus avoid it (43).

It is therefore apparent that, to establish the existence of resistant strains beyond question, one should make comparative measurements of susceptibility under carefully standardised conditions. Even where this has been done, a number of investigations have merely shown the existence of some degree of resistance by differences in the proportions killed in two colonies of insects. It is very highly desirable to obtain dosage-mortality curves to estimate the level of resistance quantitatively and also to see how it is distributed throughout the population. Unless we use precise reliable methods to measure resistance itself, any more advanced investigations on the genetics or the biochemical mechanisms involved are seriously handicapped. Therefore it is not merely pedantic to criticise a widely used method of measuring resistance in house-flies by applying measured drops of acetone solutions. Fallaciously high values may be expected to result from dosing with volatile solvents or exposing insects to dry crystals of insecticides, because the proportion actually penetrating the cuticle falls off steadily as the dose increases. This method has resulted in inflated values for resistance: for example, one strain of house-flies was found to survive 16 times the normal dose of DDT applied in oil but 300 times the normal when acetone solution was used (5). In view of these sharply contrasting results obtained by different methods, comparison should perhaps be in relation to some parameter of the normal curve of distribution.

An accurate method of measuring levels of susceptibility is also of value in detecting low-grade or incipient forms of resistance. It is encouraging to know that the World Health Organisation is advocating tests of the levels of resistance of disease-carrying insects at the start of control campaigns based on insecticides.

The significance of the actual magnitude of resistance from the immediate practical standpoint may differ from its theoretical implications. In some circumstances a comparatively small degree of resistance may render control impossible. Thus, the cyanide tolerance of the resistant scale insect *Aonidiella aurantii* is only 2–4 times normal (22, 28); but concentrations of hydrogen cyanide that would kill it would be lethal to the citrus trees. On the other hand, laboratory strains of house-flies resistant to pyrethrins or to phosphorus insecticides have been found of the order of ten-times normal and it is generally believed that these can be controlled by increased dosage, provided that the resistance does not increase further (30). At least, this is a great contrast to the resistance of house-flies to chlorinated-hydrocarbon insecticides, which may reach levels of several hundred times normal.

From the theoretical standpoint, it is important to know how common are resistant strains of different levels in various species of insects. This should give some clue to probable trends in the future. The view is sometimes expressed that resistance is an inevitable result of the wide use of insecticides, a view often supported by a recital of the heterogeneous list of cases, already mentioned. On careful examination, however, it appears that true insecticide resistance has been established without question only in the following instances:—

Aspidiotus perniciosus	Lime-sulphur	Washington	1914 (27)
Aonidiella aurantii *Saissetia oleae*	Hydrogen cyanide	California	1916 (35)
Boophilus decoloratus	Arsenic	South Africa	1940 (9)
	γ BHC	,, ,,	1948 (47)
Scirtothrips citri	Tartar emetic	California	1941 (34)
Musca domestica	DDT	World wide	1947 (46)
	Chlordane, BHC	,, ,,	1948 (25)
Culex	DDT	Italy	1947 (29)
Aëdes taeniorhynchus *Aëdes sollicitans*	DDT	Florida	1950 (7)
Aëdes nigromaculis *Culex tarsalis*	DDT	California	1950 (2)
	Chlordane, BHC	,,	1951 (10)
Anopheles quadrimaculatus	DDT	Tennessee	1952 (21)
Anopheles sacharovi	DDT	Greece	1953 (23)
Culex fatigans	DDT	Réunion	1953 (11)
Tetranychus bimaculatus	Phosphorus insecticides	New Jersey	1949 (39)
		Pennsylvania	1949 (39)
Pediculus humanus	DDT	Korea	1952 (18)
		Egypt	1953 (5)
Blattella germanica	Chlordane	Texas	1953 (16)

Laboratory-selected strains have been omitted from this list; none has shown a high level of resistance, except those from species (like the house-fly) that have produced refractory strains in the field. For example, several workers have tried to produce DDT-resistant strains of *Drosophila melanogaster* for genetical studies, but they have reached only comparatively low levels (24, 31, 37, 42, 44, 45).

Two things are specially noteworthy in considering this list. If laboratory strains and dubious cases are excluded, remarkably few pest species developed resistant strains before the last 10–15 years. It is not clear whether this is due to the exceptionally wide use that has been made of new synthetic insecticides, or whether there is some characteristic of the poisoning processes of the chlorinated-hydrocarbon insecticides that allows insects to develop protective mechanisms.

A second noteworthy point is the preponderance of pests of medical importance and relative paucity of agricultural pests. In a recent American article (20) there are suggestions of failure to control the following field pests in 1953: grape and apple leafhoppers, cabbage looper, imported cabbage worm, potato beetle, *Lygus* bug on alfalfa, flea-beetle, potato aphis and green peach aphis. But these failures have not been definitely proved to be due to resistant strains, and even so they represent a comparatively small fraction of the many hundreds of pests against which insecticides are used regularly. It seems likely that any given species can more readily develop resistance to some insecticides than others, and conversely that the capacity to develop resistance varies considerably in different species.

Here I must admit that to speak of " development of resistance " may give rise to misconceptions; to say that an insect " acquires resistance " is even worse. These phrases seem to imply that individual insects can become tolerant of insecticides by exposure to sub-lethal doses. On these grounds, people sometimes make unjustified assumptions, such as that resistant strains are most likely to develop when insecticides are used inefficiently and cause only low mortalities. Actually, instead of sub-lethal doses inducing resistance, there is some evidence that such poisons as DDT are cumulative in action on insects as well as on vertebrates (38). Furthermore, it is well known that resistance is inherited, and it has been shown that the male parent can transmit it as well as the female. Therefore, cytoplasmic inheritance of modified enzymes (as Hinshelwood has postulated for resistant bacteria) does not obtain with insects.

Most resistant strains are probably the expression of abnormal genes after selective mortality has eliminated the susceptible members of the population. The possibility of the development of resistance in any species and the speed with which it would happen, would depend on three factors:

(i) The frequency of occurrence and the effectiveness of resistant genes in the pristine population.

(ii) The intensity of selection, *i.e.* the magnitude of the population exposed to insecticide and the proportion killed.

(iii) The number of generations per year.

As a matter of observation, resistance has been noted in the field after about one or two years' intensive use of the newer insecticides: *e.g.* cattle tick (BHC), thrips (tartar emetic), house-fly (DDT), spider mite (phosphorus insecticides), lice (DDT). The mosquitos have been generally a little slower and have generally not shown difficulty until after five years' treatment. After resistance to DDT has been established, a change to other chlorinated hydrocarbons brings resistance to BHC, chlordane and dieldrin within a year in house-flies and culicine mosquitos.

Comparatively few strains of insects from different areas have been examined for resistant individuals prior to the wide use of insecticides against them. Such tests as I have made on body lice and mosquitos (6) have shown no evident differences in susceptibility of colonies from various localities. Since the signs of resistance do not appear rapidly, it is likely that resistant genes are rare in natural populations. A probable reason for their rarity is that they may involve some deleterious effect apart from their action in relation to insecticides. For example, several American workers have observed that DDT-resistant house-flies have a rather longer life-cycle than normal ones. This might conceivably be disadvantageous in natural competition in the absence of insecticide, and the normal strain would gradually supersede the resistant one. The rate of decline would depend on the importance of the deleterious effect and the extent to which the resistant strain had replaced the normal.

Laboratory colonies of resistant scale insects have retained their resistance for six years in the absence of exposure to hydrogen cyanide (49); I have a colony of chlordane-resistant flies that showed no decline over a period of four years (80–90 generations) in the absence of selection; red spider mites have been reared for ten months (20–25 generations) without loss of resistance to parathion (39). These indications of possibilities are interesting, but it must be emphasised that laboratory colonies differ widely from field populations, not only in environment but also in genetic potential.

Comparatively few studies of the genetical basis of resistance have been made. The technique is difficult, since one usually has to kill the insect in order to measure the degree of resistance.

Two investigations of the inheritance of cyanide resistance in red scale led to the conclusion that the genes for resistance or susceptibility were sex linked (8, 49). From either reciprocal cross, the F_1 females were intermediate in character, while the F_1 males resembled their mother.

The apple-penetrating faculty of certain codling moths can be inherited and has been investigated by mass-crossing tests (17). The F_1 progeny were intermediate in resistance, and the two back-crosses to the parental lines were again intermediate between the hybrid and the respective parent.

As mentioned earlier, laboratory selection can produce insecticide-resistant strains of *Drosophila melanogaster*, though of a different type and degree from that shown by house-flies. Genetical experiments on one such strain in Japan have shown that resistance to both DDT and BHC may be due to a single dominant gene on the second chromosome (44).

Investigations of the genetics of DDT-resistance in the house-fly have given contrasting results by two different techniques. Mass-crossing tests in which susceptibility was measured by percentage mortality in groups of treated flies, gave results indicative of multigene inheritance (3). On the other hand, two independent investigations in which the speed of action of DDT was taken as a measure of susceptibility showed segregation in the progeny typical of a single recessive gene for resistance (12, 19). It appears that the discrepancy may be due to the fact that two distinct defence mechanisms against DDT can occur in house-flies and these may be inherited in different ways.

This brings up the problem of the means by which certain insects are able to tolerate abnormally high doses of insecticides. Since the modes of action of most insecticides are still very obscure, it will be appreciated that this is a difficult problem. Various investigations over a span of 40 years have not revealed the secret of the cyanide-resistant scale insects. Only negative results have been obtained, as for instance that resistance is not due to a property of the wax covering or, apparently, to an enhanced facility for so-called " protective stupefaction " (36).

Virtually nothing has been elucidated about the mechanism of other types of resistance except with house-flies. It was shown quite early that fly resistance was not due to an impermeable cuticle, for the tolerance is manifested when the insecticides are injected (1). This is not very surprising, for the specific nature of resistance in house-flies suggests a biochemical rather than a physical defence mechanism. A promising lead by some American workers was the discovery that resistant house-flies could chemically degrade DDT by dehydrochlorination to the innocuous DDE, while normally susceptible flies could not or could do so or at only a very low rate (40). This was confirmed in a number of other laboratories, and there was evidence to show that the process was enzymatic (though the enzyme concerned must surely be a very unusual one). Most of these investigations have been done by microchemical methods, involving measurements of minute amounts of DDT and DDE extracted from treated flies (32, 48).

Two criticisms have been levelled against this theory of DDT-resistance. The degradation of DDT inside the flies is slow and not complete, so that resistant flies may behave quite normally while carrying inside them a dose far above that lethal to normal flies. But this is not a serious objection, for it is probable the accumulations of insecticide in certain regions (*e.g.* fat-body) might be quite harmless except for the constant diffusion of toxicant to vital centres. If the enzymatic degradation is adequate to neutralize this seepage, the insect would not become intoxicated. A second objection to the " dehydrochlorination theory " is that the chemical degradation of DDT by resistant flies might be a result of their longer survival and not a cause of it. Dehydrochlorination of DDT ceases after the flies die, and the susceptible ones are of course killed by much lower doses. The counter to this objection was also found in American laboratories, where various compounds have been discovered that will inhibit dehydrochlorination of DDT by resistant flies (32, 41). Some of these, for example DMC, are DDT analogues (26) that are selectively attacked by the enzyme, leaving the DDT unchanged (33). As a result, the resistance to DDT largely (but not entirely) disappears and the resistant flies are killed. This seems to establish the dehydrochlorination mechanism as one type of defence against DDT in the house-fly. But it is equally clear that it is not the whole story, nor perhaps, its most important part. Some three years ago I was able to show that there are two distinct defence mechanisms against DDT, which can be present to different degrees in various strains of house-fly (4). The defence depending on dehydrochlorination (which is slow) does not protect the flies from initial paralysis: they are knocked down but they subsequently recover. The flies that strongly develop the unknown mechanism are quite unaffected by DDT at any stage and are resistant to DDT analogues, such as di-anisyl neo-pentane, which cannot suffer dehydrochlorination (5). As already noted, these two systems seem to be inherited in different ways.

Highly resistant strains of flies probably have both mechanisms well developed; but certainly the second mysterious system is always present; as shown by their immunity to DDT paralysis. Furthermore, when flies are sprayed with DDT plus a synergist (thus killing those depending on dehydrochlorination alone), strains resistant to the combination arise in a few generations (26).

So far we have been considering resistance to DDT and its analogues. But house-flies (and other insects) can display resistance to other chlorinated hydrocarbons, and this is a distinct and independent phenomenon. There is a group of insecticides that includes γ BHC, chlordane, dieldrin, aldrin, isodrin, endrin and toxaphene to which flies may become resistant. Selective mortality by one of these compounds raises resistance of a strain to the others, to different levels. I have recently examined four strains of house-flies from quite different parts of the world, and all showed the same pattern of resistance to this group, whether the resistance was caused by field use of BHC or chlordane. It seems probable that a single mechanism copes with all compounds in this group.

The common factor in this series appears to be a steric character: a group of five symmetrical chlorine atoms that appears in molecular models of all of them.

I should like to conclude with a few general observations on the whole subject. It is surely not necessary to dwell on the practical importance of insecticide resistance. In the field of medical entomology we feel considerable anxiety about the possibility that resistant strains may win back for disease the new conquests that we have made in recent years by the use of insecticides. No doubt there is a similar threat in the agricultural field.

I hope that my talk has emphasised the wide gaps in our fundamental knowledge of resistance. This ignorance makes it very difficult to answer the questions of the field user of insecticides. It is very difficult to predict the future when one does not exactly understand what has been happening in the past.

It is customary at this point to emphasise the need for basic research. But in my experience the fundamental research worker is seldom tempted to investigate problems because of their practical importance. As an alternative suggestion, we might point out the large variety of fascinating problems involved, interesting on their own account in relation to invertebrate physiology and biochemistry, not to mention genetics and population dynamics.

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Discussion

The CHAIRMAN said that Dr. Busvine had given an excellent introduction to the fundamental aspects of acquired resistance, particularly to chlorinated insecticides. He invited discussion on both the fundamental aspects of the subject and practical application.

Dr. F. VAN EMDEN asked whether the development of a rufous strain of house-flies that had been submitted to him from Dr. Busvine's laboratory was connected with resistance. Dr. Busvine replied that the laboratory investigations had been carried out by using small colonies with a lot of inbreeding, and that certain changes (wing malformation, light eyes, etc.) often developed in these circumstances. The rufous character was one of them and had no connection with resistance.

Dr. W. PETERS said that observations in West Africa where residual sprays of dieldrin, DDT and BHC were being used in a project for malaria control formed an interesting illustration of Dr. Busvine's remarks. In less than a year after the initial spraying the population of house-flies (*Musca domestica vicina*) in the dieldrin areas rose to a much higher level than had ever been known in the country before. Laboratory tests showed that the flies were 200–300 times as resistant to dieldrin as normal laboratory strains studied by European workers, and were also resistant to DDT and BHC. Pre-spraying figures for the susceptibility of the local flies were not available.

The question arose why the population increased far beyond its original level, and this linked Dr. Busvine's remarks with those of Dr. Massee. Was it a case of the disturbance of the balance of insect populations by the destruction of the predators, or was it entirely a question of resistance to the insecticide ? There appeared to be a lack of literature on the ecology and normal predators of the house-fly, and these required further study.

The CHAIRMAN enquired whether the explanation could be a neglect of hygienic measures resulting from too much reliance on the highly effective insecticide, but Dr. Peters replied that it was not, stressing that the findings were purely incidental to the use of the insecticide for mosquito control.

Dr. F. L. VANDERPLANK asked what was the effect of oil as an insecticide solvent, and also whether anything could be said about the possibilities of the development of resistant strains in a Coreid attacking coconut in Zanzibar and the ants associated with it. He pointed out that the Coreid had some 6–7 generations a year and was being sprayed some 4–6 times a year with DDT, while the ants had only one generation a year. He added that sublethal doses of DDT affected the Coreid by accelerating the moulting of nymphs and the oviposition of adult females.

Dr. BUSVINE replied that when resistance of flies to DDT was being measured by topical application of solutions, the results if the solvent was oil were very different from those if it was acetone. One strain of flies showed 16 and 300 times the normal resistance to DDT in tests in which oil and acetone, respectively, were the solvents. The very high resistance shown with the volatile solvent was an artefact, caused by the fact that when the solvent had evaporated, the crystalline DDT remaining almost ceased to be absorbed.

As regards the liability of species to develop resistant strains, the frequency with which resistant genes occurred in the natural population appeared to be a far more important factor than the number of generations a year. House-flies and mosquitos had similar numbers of generations, but house-flies always developed resistance, whereas mosquitos had done so only to a small extent, in a few cases. Occurrence of resistant genes in as small a proportion of the population as 1 : 10,000 would, however, be important, and this would make it laborious to ascertain by tests whether they were present in the Coreid or ants. Reaction to sublethal doses of DDT had no relevance to resistance.

Dr. D. W. WILLIAMS asked Dr. Busvine what criterion he had accepted in compiling his list of authenticated cases of resistance, and whether he regarded American reports of DDT resistance in bed-bugs and cockroaches as being insufficiently authenticated. Dr. Busvine replied that his criterion was published results of laboratory tests. He had heard of these and other cases, but he did not include reports of the finding of resistant strains in nature until their resistance had been authenticated in the laboratory. He regarded these reports as an important source of information on which research could be based, and stated that WHO contemplated the collection of information on the appearance of incipient resistance.

Dr. I. THOMAS asked whether there was a case for the collection by FAO, or some other organisation, of similar information about agricultural pests. Dr. Busvine considered that this would be most desirable; information came in from commercial and similar sources and it was important to check it as soon as possible. The test method would have to depend on the insect and poison but, if suitable simple tests could be devised, it would be excellent to test the progress of resistance from time to time.

Mr. L. W. L. COLE referred to Dr. Busvine's remarks concerning the misleading results obtained if a volatile solvent were used in tests of the insecticide resistance of house-flies, and pointed out that the carrier commonly used was kerosene. This should be as free as possible from aromatic compounds (a " lighting " rather than a " power " kerosene). The aromatic compounds in non-deodorised kerosene were often distinctly insecticidal in themselves.

He also said that Dr. Peters' results with dieldrin in West Africa suggested the presence of unusual conditions. Dieldrin had been used for some years and on a large scale in some countries for the control of insects of importance in public health, but he was not aware of any other case in which house-flies had developed resistance in the manner described.

Dr. BUSVINE said that most cases of resistance had been reported from temperate regions where insecticides had been extensively used because fly populations were very large. Dr. Peters' work had been carried out in a damp tropical region, where flies tended to be comparatively rare, despite the apparent suitability of conditions; it might be that they were kept down by natural enemies and that these were destroyed by the dieldrin.

Mr. K. F. GOODWIN BAILEY referred to the effect of the solvent in laboratory tests of insecticide resistance. Did the normal strain of the house-fly show a marked difference in reaction according to the solvent used in the same way as a resistant strain ? Dr. Busvine explained that the marked difference due to the solvent was the difference between the reactions of the normal and resistant strains; the flies were treated with measured droplets of insecticide in solution, but the higher concentrations of DDT in the acetone droplets to which the resistant flies were exposed did not result in a penetration into them of a correspondingly increased amount of DDT, so that the apparent increase in dosage was fallacious.

The CHAIRMAN said some held the view that all the well-known sanitary measures for control were being jettisoned, and insecticides used as a bludgeon, and that if insecticides had been regarded as supplements and not substitutes for the well-tried methods, resistance would not have developed as it had done. This view should be borne in mind in the future.

Dr. BUSVINE, remarking that most of authenticated instances of resistance were in pests of medical importance, asked if any one could give information on resistance developing in agricultural pests.

Mr. A. D. PICKETT replied that many examples could be given. Resistance to lead arsenate in the codling moth had been demonstrated 20 years ago in Virginia, where it had 3–4 generations a year, and became evident ten years ago in Nova Scotia, where it had only one. It had also developed resistance to DDT in some areas where it had several generations a year, but had not done so in Nova Scotia, where DDT was not extensively used, ryania being preferred because it was selective. Commenting on the need for authentication of resistance by laboratory tests he suggested that, where experienced workers made seven applications of DDT in the orchard and ended with 95 larvae per 100 apples, resistance was probably present. There were probably many other examples of resistance, as it was observed each year that additional insects were not being controlled with insecticides that had previously been effective. It appeared to be fairly certain that the bud moth (*Spilonota ocellana*) was resistant to lead arsenate.

Dr. I. THOMAS said that there was just a possibility of resistance having been built up in two instances in orchards in England, since the fruit-tree red spider did not now seem to be adequately controlled by lime-sulphur washes although it had been in the past, and failures to control fruit-tree Aphids by tar-oil washes had been more frequent in recent years than previously.

Mr. L. A. LICKERISH referred to reports from Indonesia of strains of *Plutella maculipennis* resistant to DDT, and to the well-known case of resistance to parathion and HETP in greenhouse red spider in the United States. The latter case was interesting because, when reports of resistance to parathion were investigated, it was found that the resistance had been built up in previous years by the use of HETP, but was not brought to notice until parathion was used.

Dr. A. M. MASSEE agreed that lime-sulphur was effective against the fruit-tree red spider 7–8 years ago, and said that concentrated lime-sulphur had recently given little or no control of this mite. He attributed recent failures to control fruit-tree Aphids by winter washes, notably in the west Midlands, to less efficient and discriminating methods of application, owing to the cost and shortage of skilled labour. He deplored the tendency to use spraying machines as if they were fire-engines.

Mr. H. E. HARBOUR said that the one-host cattle tick, *Boophilus microplus*, now showed strong resistance to toxaphene in an area in southern Brazil. In Africa, the one-host tick, *Palpoboophilus decoloratus* had in some areas become resistant to arsenic and BHC and, to a less extent, to toxaphene, whereas the two- and three-host ticks (*Amblyomma*) in the same areas could still be controlled by these acaricides. It was also of interest that the BHC-resistant cattle tick of South Africa was still susceptible to DDT.

Dr. BUSVINE said that Mr. Harbour had raised a very important point, illustrating the fact that the development of resistance depended on the proportion of the population that was being affected by the insecticide. If part of the population was not exposed, its members diluted the part that was, and so retarded the process of selection for resistance. Thus, in contrast to house-flies, many members of a mosquito population were not domestic and so escaped contact with insecticide deposits and diluted that part of the population that had been selected for resistance. Similarly, as two-host ticks were not always on cattle they would be subject to less pressure of selection for resistance than one-host ticks.

The CHAIRMAN asked whether two-host ticks were confined to a single host as adults, and Mr. Harbour replied that they usually had a number of alternative hosts.

Dr. D. W. WILLIAMS said that, in the control of pests of stored products in Scotland, cleaning without the use of insecticides was considered better than the converse. General hygiene could not be neglected.

The CHAIRMAN, in closing the discussion, referred to Dr. Busvine's plea for a study of the nature of acquired resistance. This and the mode of action of insecticides were interlocking problems, and one could not be understood without the other. One of the best ways of studying mode of action was to study resistance. The present ignorance of mode of action was not confined to insecticides but applied to most poisons; it was only of recent years that any knowledge of the action of familiar poisons had been acquired. To extend this knowledge we required detailed studies of the metabolic enzymes.

DISCUSSION ON THE SUPPLY AND TRAINING OF TAXONOMISTS

Chairman: Mr. N. D. Riley, C.B.E.,
Keeper of Entomology, British Museum (Natural History)

Opening Speaker: Dr. W. J. Hall, C.M.G., M.C.,
Director, Commonwealth Institute of Entomology

The CHAIRMAN said that taxonomy had become a subject of increasing complexity. Insect specimens brought to the British Museum 50 years ago were then named with some confidence, but it was now known that many had been named wrongly. Insects that were referred to one species in one territory might be referred to two in the next. The best taxonomic experts were the most diffident, but economic entomologists had to have names for the material with which they worked, and a practical solution to the problem had to be found. He called upon Dr. Hall to outline the salient features of the able memorandum that he had prepared.

Dr. HALL gave a summary of the memorandum, the text of which is published elsewhere in this Report (pp. 151–154), because although it had already been submitted to the delegates to the Conference, it had not been seen by all of the taxonomic workers present at the meeting. He then said:

If the Conference is in general agreement with the situation given in the memorandum, I suggest that, after the subject has been discussed, a small Committee of delegates might be set up to draft resolutions in the light of the discussion and calling for action designed:—

(*a*) to strengthen taxonomic research in general,

(*b*) to strengthen the identification services along the five lines suggested in the memorandum.

To enable these two general resolutions to be amplified, I suggest that the following points might be among those discussed.

Taking taxonomic research first:

1. The desirability of providing additional facilities and finance for national collections where these exist.
2. The need for professional training for taxonomists and curators. Where is this to be obtained and how is it to be financed? Should the onus of providing it rest on the museums?
3. The need to make the career of a taxonomist more attractive by improved opportunities for overseas collecting and travel.

Turning now to the identification services:

1. The need to build up regional reference collections of species of economic importance. How should these be arranged and staffed? Should it be as part of an Agricultural Department, or attached to Universities and linked to teaching, or should regional museums be set up?

2. The institution of studentships or fellowships, financed by research grants for limited periods to postgraduates or oversea university workers or departmental workers on a study-leave basis for regional studies.
3. Strengthening of mixed taxonomy and identification in special groups. New posts might be created to make studies of all stages of a certain class of insect pest on a particular crop, involving opportunities for field work in the Commonwealth coupled with study, at an appropriate museum of the material collected.

The CHAIRMAN thanked Dr. Hall and ascertained from a show of hands that the meeting endorsed the general sentiments of his analysis of the situation.

Mr. I. F. B. COMMON said that one of the most important points in Dr. Hall's admirable summary was the emphasis on the need for critical revisionary work. The difficulty of obtaining a reasonable financing of taxonomy in universities and museums would not be resolved until biologists in general became convinced of the importance of taxonomic work. Too many were prepared merely to give lip-service to the principle without being convinced of the necessity for a great expansion of taxonomic research. This, he thought, reflected a deficiency in the taxonomist rather than in the general biologist.

The work of the insect ecologist, the applied entomologist, and even the insect physiologist demanded a reliable taxonomic foundation. These workers might be regarded as consumers and the taxonomist as the supplier of a very specialised product. Nothing caused the consumer to become more sceptical about the value of a certain industry than a shoddy product.

The shortcomings of the taxonomist were often due to a lack of the right kind of training, but where this was available, taxonomy of high quality still required, as its tools of trade, the provision of libraries, equipment and access to authentic reference collections. Adequate finance could provide the first two, but an authentic reference collection, which was a pre-requisite for the study and description of new forms, could only be built up on a basis of critical revisionary work.

In Australia, at least, the greatest need was for this thorough, revisionary assessment of what had already been done, usually by oversea workers whose types were deposited in a variety of oversea museums. Access to these type collections presented the greatest difficulty and discouragement to taxonomic workers in Australia, and frequently led to the publishing of uncritical results or an abandonment of the work. It was implicit, in Dr. Hall's address, that it would become more and more necessary for the larger members of the British Commonwealth to assume the burden of their own identifications and critical revisions. Any measures that might enable Commonwealth taxonomists more easily to make an exhaustive study of the types of the insects that occurred in their own countries would improve the quality of their work and the status of their profession, and would also assist in maintaining the interest of the younger taxonomists.

Mr. Paul FREEMAN pointed out that when a taxonomist had revised a group, there was a tendency to send all material of that group to him for identification rather than to use the key published in his paper. Moreover, to achieve a large output of synoptic papers, a taxonomist had to switch from group to group, which meant that the material he wished to receive was not that of the group he had just finished. Mr. Freeman thought it was difficult to train entomologists to be taxonomists unless they already showed a bent in that direction; it was more important that such persons should be encouraged by the offer of grants to work on problems at, for example, the British Museum.

Prof. V. B. WIGGLESWORTH suggested the substitution of " luring " for " training ". Teachers had the first opportunity of luring students, and at Cambridge, although the accent was placed on studies of functional aspects, such as physiology and ecology, the importance of systematics and taxonomy was fully appreciated; the students were subjected in their final year to a course in insect morphology, systematics and taxonomy and this gave opportunity for enticement. Mr. Freeman had suggested the provision of grants. These existed at Cambridge, where there were also extensive and very good collections of British insects, close touch with the British Museum, and space for the training of taxonomists. Despite this, and although there were a number of students with an interest in taxonomy, they did not offer themselves as taxonomists because they did not want a life buried in a museum. Dr. Hall's suggestion to make taxonomic work more attractive, by providing opportunities for travel, for example, was therefore constructive. Another point was that, where improved facilities existed, they should be advertised. He would like those who wanted taxonomists to come and talk to students. It was necessary for those who came, however, to be both enthusiastic and honest about the subject, and to say the right thing. He had had experience of exactly the opposite.

The CHAIRMAN, referring to Professor Wigglesworth's point of a life cloistered in a museum, said that this should be an exploded idea. It was his deliberate purpose to get as many of his staff overseas as possible. There had been a vast change of opinion during the past 40 years, and the widening of outlook obtainable by tropical experience was recognised.

Dr. F. VAN EMDEN said that two difficulties stressed in the discussion seemed to be (1) the strain imposed on taxonomists by the need to differentiate forms that were hardly, if at all, distinguishable morphologically but were found by field workers to differ biologically; and (2) the dearth of students who were prepared to choose systematic work as a career. He believed that both difficulties could be considerably reduced by the creation of facilities for work in " experimental systematics " at scientific institutions with systematic activities. At present, taxonomic workers often felt frustrated by being obliged to distinguish forms that appeared indistinguishable and by being unable themselves to carry out experiments on systematic characters of a biological nature. Moreover, the young entomologists interested in taxonomy would probably be more willing to be " buried in a museum " if part of their work could be of an experimental kind.

Dr. John SMART said that, in spite of the increase in the number of graduates in biological sciences coming from the Universities, a shortage of taxonomists continued. The increase in taxonomic studies and the provision for them had not been nearly so great as that in other specialised and applied branches or in biological work generally. It could be said, broadly, that in pure zoology interest now centred on comparative physiology, this being linked, through studies of behaviour and the reaction of organisms to environment, to problems of ecology and population.

In the United Kingdom, and probably elsewhere in the Commonwealth, entomologists were trained as zoologists with an orientation to entomology. Training elsewhere in the English-speaking community (North America especially) was more specific, and the young trained entomologist might have only meagre grounding in general zoological theory; he had some time for taxonomy. It thus came about that British entomologists were being reared in an atmosphere in which, although the importance of taxonomy might be admitted, the centre of intellectual interest was definitely non-taxonomic. The student soon sensed what were the focal points of research towards which the minds of most of his teachers were orientated; he noted which subjects got most financial support; he saw which fields of work provided most jobs and so calculated that his chances were best in one of them; he noted which lines of research appeared to bring honours in their train or lead to senior posts.

Some students were born systematists and would move into taxonomy whatever happened, others would never make taxonomists under any circumstances. Between these two groups, however, there were a number of students who could become competent taxonomists if their attention could be drawn towards systematics in a sufficiently early stage in their training.

In spite of the facts that additional lecturers interested in taxonomy had been appointed to the universities, that it was known that financial support would be forthcoming for post-graduate work in taxonomy and morphology, and that attention was periodically drawn to the shortage of taxonomists, this shortage persisted, and the troubles in other branches of zoology that resulted from it were increasing and were more specifically recognised than ever before.

Dr. SMART then said that, having spent ten years working in a taxonomic institution, followed by over seven years in a university department of zoology trying to produce potential taxonomists, he ventured to put forward the following as requirements in order to step up the production of taxonomists from the training ground—the universities.

1. A joint consultative and co-ordinating committee of " consumers " and " producers " (the British Museum (Natural History), the Commonwealth Institute of Entomology, the Ministry of Agriculture, etc., with the university teachers responsible) should be set up.

2. The national institutions dealing with taxonomy should co-operate in the provision of illustrative material for the use of the university teachers.

3. The introduction of university teaching in taxonomy in such a manner as to produce taxonomists cannot be brought about by the mere appointment of Lecturers and Readers; provision must also be made for the auxiliary services needed for modern taxonomic work.

4. Careful consideration must be given to the point in the curriculum at which teaching in modern taxonomics should be introduced. At Cambridge, this is in the third year, but it should perhaps be earlier, in order to maintain the ardour of the youthful collector.

5. A number of post-graduate scholarships should be created, restricted to students prepared to do taxonomic work. The national taxonomic institutions should be prepared to co-operate by allowing these scholars, who would, presumably, be registered for Ph.D. degrees, to spend time in the institutions and receive some instruction from the experts there.

6. Professional prospects should be assured.

Two assumptions are made in the foregoing: first, that the practice of training entomologists as zoologists with an interest orientated towards insects will continue; secondly, that the major institutions of taxonomy will continue to recruit their staff largely from honours graduates in biological sciences, except for the occasional man who happens to have become an outstanding specialist.

Mr. J. A. WHELLAN considered that the failure of field workers to use published taxonomic papers, was partly the fault of the papers. Many of these, other than complete monographs or revisions of groups, contained descriptions of one or a few new species, without any comparison with better known allied species. The published descriptions of the latter were often inaccessible to workers in the smaller oversea territories. Much of the value of the paper on the new species was thereby lost; to avoid this it should include a key and references to differences from allied known species or even brief descriptions of the salient features of these.

Dr. J. W. EVANS said that however many new appointments were made there would still not be enough taxonomists. All the discussion so far had suggested that taxonomists were a class apart and spent their lives buried in museums, but there were many applied entomologists at the meeting who were also experienced taxonomists. It was true that most of those in this category were among the older entomologists, but if young applied entomologists with some leaning to taxonomy were to adopt groups of interest and importance for taxonomic study, a useful contribution of benefit to entomology as a whole would result.

Dr. R. H. Le Pelley considered that though there might be difficulties in filling some of the taxonomic posts that already existed, the actual number of posts was far too small, and that those concerned with the allocation of funds should be brought to realise that taxonomy was basic to the work of the applied entomologists and was of the highest economic importance. Nearly all the major pests of Kenya were going under different names from those that they had 25 years ago, and the former errors in identification had caused great delay in the establishment of control. This provided a concrete example for administrators of the economic value of taxonomic work.

Prof. G. C. Varley said that taxonomists were made long before the university stage, but the wastage was enormous. Some continued taxonomic work in an amateur capacity, and more use should be made of them. Mr. Riley was right in giving members of his staff at the British Museum opportunities to travel overseas; this would, however, increase the number of types of oversea species held at the British Museum, about which Mr. Common had expressed concern. The insect types at the Hope Museum at Oxford were available in certain cases to institutes abroad.

Mr. H. L. G. Stroyan said that he would like to emphasise, in relation to the taxonomy of Aphids, what Dr. Van Emden had said about experimental taxonomy. It was essential that genera in which morphological differences were minute and overlapped should be approached in the first instance from the aspect of biological criteria. The facilities urgently required were adequate insectaries, vivaria, glasshouses and technical aids for plant-rearing and the like, so that critical groups of species could be studied alive and, when dead and preserved, be fully documented as regards their biology. Only thus could the worker with dead material have a clue where to draw his boundaries between morphologically overlapping forms. This kind of facility was lacking in nearly all kinds of institutions responsible for promoting taxonomic research.

Mr. Common strongly endorsed these views. Some of the most important problems of taxonomy were presented by the oversea countries of the British Commonwealth. It was in those countries themselves that the experimental approach to taxonomy could best be effected and that taxonomic work should be encouraged. The Chairman and Prof. Varley had both referred to the opportunities for travel provided for taxonomists at the British Museum. This should not be a one-way process. Provision of fellowships for taxonomists in other Commonwealth countries to study here would be of great assistance in fostering work in those countries.

Prof. J. W. Munro said that in his experience there were quite a number of first-class students interested in taxonomy whom it had been necessary to discourage, because of the limited number of posts and the limited prospects so far available. People of the right kind did not therefore take up scholarships.

It might help in the development of taxonomy if it were more closely linked with genetics and ecology, and some advance in this direction had been made. A Reader in Taxonomy had been appointed in University College, London, and a unit for termite research, including taxonomy, had been attached to the Commonwealth Institute of Entomology. More of these special teams were wanted.

He welcomed the proposal to set up a committee, and felt that this should make specific, concrete proposals for more funds from bodies that were concerned with finance and interested in using the results of taxonomic research. These comprised the Agricultural Research Council, the Nature Conservancy, the Department of

Scientific and Industrial Research, the Ministry of Agriculture, and the Colonial Office (C. D. & W. Fund).

Mr. A. B. Baird said that in Canada the number of amateurs working in the field of insect taxonomy was very small; this work was largely carried out by professional entomologists and concentrated in the Federal Service. Those in administrative control had fully recognised the importance of identification and had encouraged the development of research in this field. Much had been accomplished by a close association of taxonomic workers with economic and faunal survey groups that were carrying out biological and ecological studies, and by encouraging the taxonomic workers to spend periods of several weeks or even months in the field. This had been extended beyond Canadian boundaries, and specialists spent varying periods collecting and studying in the United States and in Europe, and so filling gaps in their knowledge of the groups in which they specialised, and augmenting the National Collection of insects.

Mr. G. H. Caswell suggested the possibility of arranging exchanges between members of the staffs of museums and field workers in the Commonwealth, in order to enable the field workers to study the taxonomic aspects, and the museum workers to obtain information on the biology, of the groups in which they were interested.

Dr. I. Thomas thought that the points made by Dr. van Emden and Mr. Stroyan could not be over-emphasised. As the science of taxonomy advanced, the need for joint study of taxonomic and biological problems increased.

If a Committee were set up, he hoped that it would bear in mind the desirability of having on hand vacant posts, available to be filled as and when the keen taxonomist and trained man came along.

Prof. O. W. Richards said that the number of species of insects was so large that it was unlikely that there would ever be enough taxonomists to deal with them all. It should therefore be considered what groups most needed study, and, on the analogy of the termite unit, it should be arranged that the most important groups should be tackled first.

Mr. H. Oldroyd pointed out that, in spite of much that had been said, most taxonomic work still necessarily followed old-fashioned lines, and could best be done in a large museum. This fact must be honestly faced, and students should not be lured into taxonomy by promises of long periods of field work. More efficient use should be made of the existing taxonomists by relieving them from routine identification work and using them for specialist consultation and the production of monographs and keys.

The Chairman said that the discussion had been full and interesting, but he would not attempt to summarise it. Systematic taxonomy and identification work should be complementary, but in the British Museum they were antagonistic, and he agreed that it would be good to relieve the specialist by a less highly trained man who could undertake most of the routine identifications. With regard to Professor Munro's point that the number of available posts was too small, he said that he was not allowed to fill even the existing vacancies because of lack of money, and therefore could not ask for the establishment of new ones. He then asked the views of delegates regarding the establishment of a Committee, and ascertained that all wished it to be set up and desired that its members should not be confined to delegates. A Committee of ten with authority to co-opt was then elected.* He said that it was too late to consider terms of reference, but that the Committee would consider all the points raised and particularly those raised by Professor Munro. He suggested that it would be most important to draft a resolution that would be brought before the delegates at the plenary session and would be designed to force action in the quarters from which alone relief could be expected. The delegates confirmed this suggestion.

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* A list of the elected and co-opted members of the Committee is given on p. 33 of this Report and the resolutions finally adopted by the Conference as a result of its discussions are given on pp. 11–12.

DISCUSSION ON THE ESTIMATION OF REAL LOSSES FROM INSECT PESTS

Chairman: Dr. R. H. Le Pelley,
Department of Agriculture, Kenya

The CHAIRMAN said that the three papers that would open this discussion on a very interesting subject were by Dr. Thomas, of the Ministry of Agriculture, Mr. Strickland, who was now with the Ministry but had previously worked in West Africa, and Mr. Geering, who had worked in both West and East Africa, particularly on cotton pests in Uganda. He called for their papers in the order given.

The Estimation of real Losses from Insect Pests

By I. Thomas
Ministry of Agriculture and Fisheries, Plant Pathology Laboratory, Harpenden

" When you can measure what you are speaking about and express it in numbers, you know something about it; when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." That is a quotation from Lord Kelvin, borrowed from a paper on this subject written by Roebuck over 20 years ago. When I first discovered this paper, I was very interested to see how Roebuck (1933) had set about his task of measuring the toll of insect pests in the Lindsey division of Lincolnshire in 1932. I found that he had used a method that has quite recently been used by other workers, apparently without knowledge of this earlier work.

Roebuck made three experiments in which he simulated the damage done by insects. In the first, he cut off leaves or parts of leaves of wheat at weekly intervals after the flowering period; in the second, he cut off half the leaf surfaces of mangolds and sugar-beet at intervals during the season from growing to lifting time; and in the third, he systematically thinned wheat plants and compared the losses with those from plots in which whole patches were denuded of plants.

I do not intend to discuss methods for assessing damage or results therefrom in any detail. But in passing it is interesting to note that with systematic thinning there was practically no loss of crop until 50 per cent. of the plants had been destroyed. Where the plants were destroyed in patches, the loss of yield was almost directly proportional to the loss of plants. Some 20 years later, Jones (1953), in carefully conducted defoliation trials, found that, at the four leaf stage of sugar-beet, 50 per cent. defoliation had no significant effect on the subsequent crop, and even 100 per cent. defoliation reduced the yield by less than a third. Field surveys at about this time (White, 1953) also served to emphasise the powers of recovery of sugar-beet and mangold crops.

But Roebuck carried his investigations a stage further and by a combination of the use of field observations and graphs from his experiments he calculated the losses due to several pests of farm crops. He also calculated in each case the amount of land necessary to grow and replace the lost crop. This, you will note, comes very near to the method used by Ordish (1952), who maintains that the real loss is " the land, the labour and the resources used to grow these ungathered tons ".

All this serves to remind us that, although this science of the measurement of crop losses is often regarded as very new, it was not entirely neglected by the older members of our generation. Since Roebuck's observations were made, we have advanced a few steps but not very many. In a brief paper in *Agriculture* (Thomas, 1948)

I outlined some of the earliest efforts made in this country to assess damage on a country-wide basis, and the reconnaissance surveys made in the years 1946–51 have been reported briefly in *Plant Pathology* (Empson, 1952; Cohen, 1953; Strickland, 1953; Thomas, 1954; White, 1953). Although much interesting information was obtained, these early efforts served mainly to show that " there is no easy road to accurate pest and pest damage assessment ".

In 1950, foreseeing the difficulties ahead of us, we made two appointments at Harpenden, one to deal with pest assessment work (Mr. Strickland) and one on the plant pathology side (Mr. Large). These were, I believe, the first appointments anywhere made for the express purpose of tackling this very thorny problem. Less than 18 months ago, at a symposium held by the Association of Applied Biologists (1953), a number of workers interested in plant pest and disease assessment work brought up to date the knowledge we had accumulated up to that time.

At this stage, I should like to make it quite clear that most of the pest assessment work done in this country in recent years has been the result of team work. And when I say " we ", I mean the Conference of Advisory Entomologists of the National Agricultural Advisory Service, and in particular the Pest Assessment Committee of that body. I must put in a word of praise for this Committee, because it has a most difficult task and each of its members, in his own province, has to convince the local powers-that-be of the importance of the work when it is weighed in the balance against the urgent claims of straightforward advisory work. I may say that the Agricultural Research Council are not only whole-heartedly behind the work but have themselves attempted to put the various problems with which they have to do in some sort of order of priority. In order to do this, facts and figures are vital. The need is therefore fully recognised, but to get the job done we rely on the persuasive powers of the local enthusiast. He it is who inveigles into the " pest assessment net " anyone making observations on plants, and he is deserving of praise in full measure.

Our main advance has been to tackle the problem by the method of keeping plots of a crop free from the pest being studied and comparing the yields obtained with plots on which the pest is allowed to do its worst. This of course is also the method that McKinlay (1954) used in studying damage to cotton by *Lygus* in Uganda in 1952, and I believe it will have to be the main method of the future. If only insects were as big as rabbits, our problem would be far easier. Other than by the use of an overwhelming amount of insecticide we cannot grow crops in the absence of insects without subjecting the crop to very artificial conditions. With rabbits this is possible. (Church, Jacob & Thompson, 1953).

A third method, which we have occasionally used, is to obtain from advisory entomologists their estimates of what the losses are from a particular pest in their own provinces. I do not refer here to inspired guesses but estimates made as a result of careful surveys of a pest with which the adviser is constantly dealing. I can give two examples, the first in the nematological field. We were asked by the Agricultural Research Council for some estimate of the damage done by the potato root eelworm. From routine enquiries and observations, advisers already had a good knowledge of the damage caused by this pest; and, in addition, they had surveyed and sampled a large proportion of fields in the main potato-growing areas. Knowing as they did, for particular types of soil, the levels of eelworm population that cause slight or severe damage or almost total loss of crop, they were able to provide, each for his own province, a very good estimate of the amount of damage done by this pest. Putting these figures together, we were able to calculate that the annual losses were in the region of 200,000 tons per annum.

A rather different survey was made in 1953, following the severe damage to wheat by the wheat bulb fly. In this instance, it was possible to obtain actual acreages of wheat affected to varying extents. Dr. Gough has been working on this pest for a number of years and he kindly collated the figures. They are as follows:—

Redrilled	59,000 acres
Patched	58,000 ,,
Affected but not redrilled or patched	85,000 ,,
	202,000 acres

Cost of new seed on redrilled land	£540,000
Loss on redrilled areas due to smaller yield of spring wheat	£500,000
Other losses	£250,000 to £500,000

This kind of information is of course obtainable only in a country with a comparatively large staff engaged on advisory work, but it has the advantage of being very clear-cut and convincing, and cannot be refuted.

I now wish to take up more strongly a point I have made on other occasions. It is this: how shall we integrate damage from pests with other factors that limit production? Sometimes it is the pest which is the limiting factor, and it may frequently be the pest in countries in which what may be termed the agricultural sciences are well advanced. More often, in the under-developed countries, the limiting factor is one that has been termed by Fennah (1954) " the retarded or unbalanced metabolism of the product, whether plant or animal ". In the West Indies he says that this is of overwhelming importance compared with the toll exacted by insects, and is the principal factor that determines the extent of the damage done by a large pest population. We must therefore, when we work on this problem, and especially in under-developed countries, distinguish clearly between potential loss and actual loss. The answer obtained from damage assessment work done on a peasant farm may be very different from that obtained from similar work on the same pest at an experimental farm. The limiting factors may vary widely in such cases. These factors are well summarised by Russell (1953), who points out that land plants need an adequate depth of soil, an adequate water supply, an adequate number of days when there are no serious frosts, and an adequate food supply. Anything that affects any one of these essential requirements for the plant may in certain circumstances be a limiting factor.

I believe that more co-operation is needed between the workers in the various facets of agricultural science to search out these factors, and this is true even in this country. To put it crudely, money spent on insecticides that, if they kill 100 per cent. of the pests, will raise a quarter crop to a half crop, may be money badly spent, and the entomologist has quite as important a part to play in preventing the excessive use of insecticides as he has in advocating insecticides when they are really necessary.

I began with a quotation and I will end with one—this time from a letter from one of our foremost entomologists who recently visited parts of East Africa. " When one meets here the appalling avoidable waste of food from insect and disease it makes home problems seem small beer. The Staff is much too small for the vast expanse of land. The African holding is a real headache, *I am sure it will take a century to persuade them to adopt better cultural methods let alone attempt spraying.* " The italics are mine.

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The Assessment of Insect Pest Density in Relation to Crop Losses

By A. H. Strickland

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Dr. Thomas has mentioned briefly the work on the assessment of pests and the damage they cause to crops that is being carried out as a co-operative venture by the entomologists in the National Agricultural Advisory Service under the guidance of the Pest Assessment Committee, and I would like to discuss this in some detail, so as to illustrate the method we use and the type of result being obtained. The method involves creating differences in density artificially on experimental plots within commercial fields, and comparing the yields from plots on which the pest has been kept at a low level with those from plots on which it has been allowed to build up normally. It usually enables a wide range of pest densities and yields to be obtained from a single field, and if individual fields are selected in different parts of the country with regard to the special conditions under which the host crop is grown in those areas, a fair estimate of the overall effect of the pest on the crop can be obtained. An advantage of the method is that a randomised block lay-out can usually be adapted so as not to interfere with normal agricultural operations. Where we are dependent on retaining the goodwill of individual farmers, this is an important consideration, and I should perhaps emphasise here that our work is always done on commercial crops.

For any given pest the initial approach is necessarily arbitrary. In 1951, for instance, we started some field-plot experiments on the effect of infestations by the cabbage Aphid (*Brevicoryne brassicae*) on brussels sprouts. Plots of 200 plants were replicated eight times at each site, four of them being sprayed at fortnightly intervals with TEPP, the other four remaining as untreated controls. Measurements of Aphid density were made on all plots at stated intervals throughout the season, and in the spring of 1952 we were able for the first time to relate Aphid populations directly to yield of marketable produce. On the basis of this work, and further experiments carried out in 1952, we have been able to reduce plot size from 200 to 64 plants at the expense of increasing replications from four to five per treatment at each site. In addition we have been able to replace the tiresome fortnightly TEPP spray applications by monthly or six-weekly root application of systemic insecticides, which keep the plants much freer of Aphids and at the same time do not affect cabbage caterpillars and flea-beetles, which tend to occur in small numbers on all plots every year. It is perhaps worth mentioning that we have to apply these systemic insecticides at a rate and concentration quite out of the question commercially (it would cost the farmer about £30 per acre for materials alone), and treated plot produce has to be destroyed as unfit for human consumption. We do, however, succeed in keeping our Aphid-free plants virtually free of Aphids over the whole season, which, as anyone who has tried spraying Aphids with TEPP or nicotine under field conditions will appreciate, is something of an achievement. In all, we have reduced time-expenditure per experiment from 20 to about 10 man-days per season, with a resultant increase in the number of sites that provincial entomologists are able to handle.

It seems appropriate at this point to say something about the great variability that is a feature of the experimental results between sites within a single growing season. Such variability is, of course, to be expected, and is due to such factors as differences in plant growth, initial and subsequent pest density, and pest activity. This type of variability is illustrated by the data given in fig. 1 which refer to some

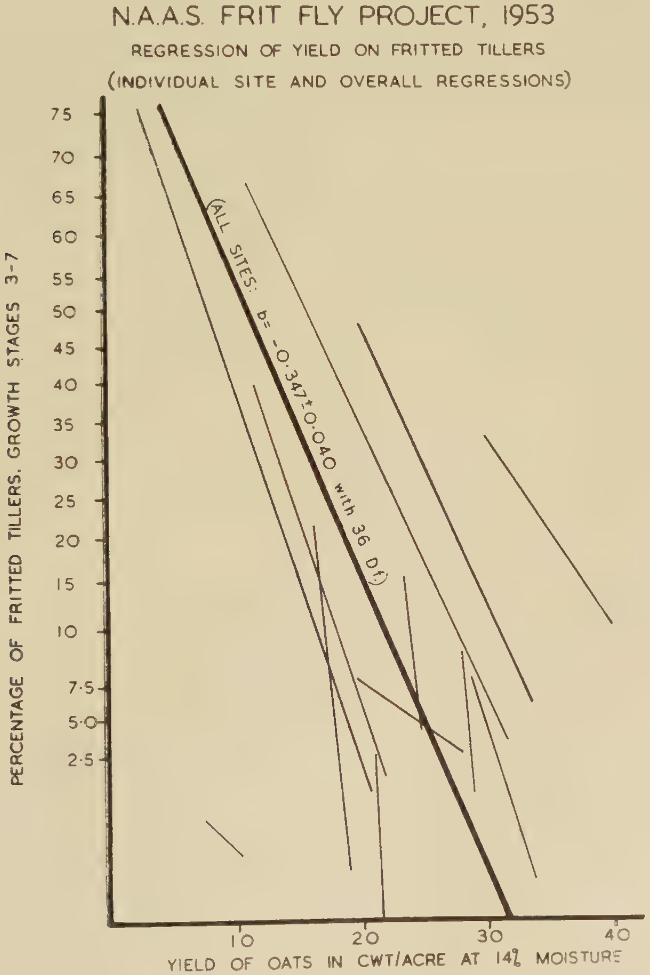

Fig. 1. Regressions of yield of oats on tiller attack by *Oscinella frit*. 12 field sites, 1953 growing season.

experiments on the frit fly (*Oscinella frit*) carried out at 12 sites last year using the widely grown oat variety " Star ". It is clear that yields were nearly four times as great at one site (Wantage, Berkshire) as at another (Starcross, Devon), yet tiller attack was greater at the first site than the second. It is obvious that results from a single site in one season cannot be used as a basis for conclusions affecting the country as a whole. Incidentally, there is also an indication in these data that up to about 20 per cent. of the tillers can be attacked without any appreciable reduction in yield.

I have already mentioned that we make pest density counts at regular intervals throughout the growing season on all plots at all sites. This is done for four reasons. First, we want to check the effectiveness of the methods being used to keep our pest-free plots pest-free. Secondly, we want to know what the pest situation is like at each site early in the season. Thirdly, we want to know something about the rate at which the pest increases; and finally we want to know what peak density it reaches on the untreated plots, and when this level is reached in relation to the growth of the hosts. We are therefore in a good position to relate pest density at any one of a number of times in the season with final host yields and, if we regard pest activity as a product of time and density, we can also relate activity to yield on a field scale.

In this connection some partial regression coefficients of yield on pest density at early and late stages in the growth of the hosts may be of interest.

Some Partial Regression Coefficients of Yield on Pest Density

Pest and site data	Degrees of freedom	Partial regression coefficients	
		Early in the growing season	Late in the season, at or near, harvest
Frit fly, 12 sites in 1953.	30	$-0{\cdot}12 \pm 0{\cdot}05$*	$-0{\cdot}41 \pm 0{\cdot}08$*
Cabbage Aphid, 14 sites, 6 in 1952 and 8 in 1953.	144	$-5{\cdot}07 \pm 5{\cdot}41$	$-14{\cdot}86 \pm 3{\cdot}68$*

(* Significant at P=0·05.)

The first point I want to make is that pest density is more closely correlated with yield at the end than at the beginning of the season. This is rather to be expected in view of the many factors that can affect a pest during the months that elapse between the emergence of the host and harvest. Secondly, it is clear that there is a negative relationship between frit-fly density early in the season, and yield. The relationship between early density of the cabbage Aphid and yield is also negative but is not statistically significant. However, if the results for 1952 are considered separately, the partial regression coefficient for the early density data is on the borderline of significance at the five per cent. point. Attack by the cabbage Aphid was quite severe in July and the early weeks of August in 1952, whereas populations were generally low until the end of August in 1953.

In short, it can be said that attack by both frit-fly and cabbage Aphid early in the season can result in a yield loss that is independent of further losses due to a continuation of the attack up to harvest. We have some evidence that frit tiller attack is closely correlated with grain attack, and similarly that there is a close association between early and late infestations by the cabbage Aphid. With information on the extent to which yield is likely to be reduced by a given pest density early in the season, the advisory entomologist can compute with some accuracy the potential benefit of control measures before he gives his advice to the farmer. This is particularly useful where recommendations have to be made about the use of expensive and highly toxic compounds that must not be applied close to harvesting.

However, I am digressing rather from the assessment of crop losses on a national scale. Figure 2 shows the two regressions that we have computed for yield of marketable brussels sprouts on a logarithmic transformation of Aphid density, along with the appropriate five per cent. fiducial limits in each case. Having computed our regression lines for yield on pest density at a given time on the basis of an appropriate number of experiments over a period of several years, we are in a good position to estimate actual yield losses provided that we have pest-density estimates referable to this time of year from a fair random sample of fields in those areas in which the greater part of the national crop is grown.*

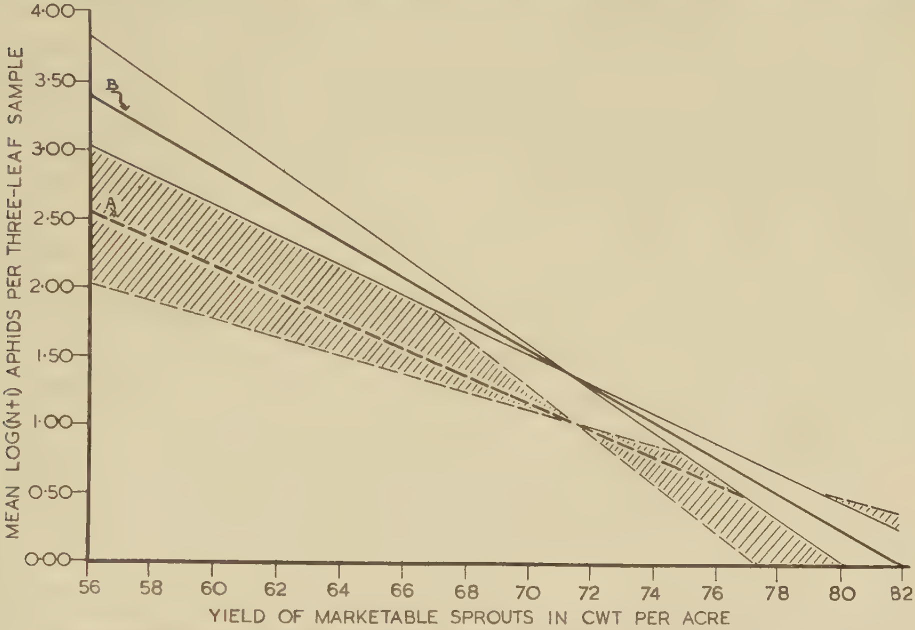

Fig. 2. Regression lines for yield of marketable brussels sprouts on log (N+1) where N=cabbage-Aphid density (*a*) within about eight weeks of planting, and (*b*) at the seasonal population peak 12 or more weeks after planting. 14 field sites in 1952 and 1953.

We obtain these estimates from rapid " Extensive Surveys " in which 20–30 fields are visited once in each N.A.A.S. province over a period of about two weeks. An estimate of pest density is obtained for each field by a standardised rapid assessment method such that not more than 20–30 minutes need be spent in any one field. It is possible, for example, to get a sufficiently good estimate of the density of the cabbage Aphid at the end of the season by examining only five plants per field. I must stress here the words " sufficiently good estimate ", because we make no use of individual field estimates. If we wanted reliable estimates for any one field, we should have to extend our sampling considerably.

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* For further information on the subject, see STRICKLAND, A. H. (1954). Assessment of cabbage Aphid damage in commercial Brussels sprouts crops. *Plant Pathology* 3 no. 4.

Results from such extensive surveys are collated at the Plant Pathology Laboratory, and an average density for the pest is computed for the major growing areas, or for the country as a whole. These averages are then used in conjunction with a regression line such as that shown in fig. 2 to estimate loss in yield for these major growing areas or for the whole country. In this way we have estimated that the cabbage Aphid caused a 17 per cent. loss of marketable sprouts in 1952 and a 15 per cent. loss

PEST INCIDENCE REPORT.													
PEST					CROP					VAR			
FARM										COUNTY			
DATE						MAP REF.							
TYPE OF AGRICULTURE			ARABLE: (R) (C)			PAST:	MIXED:	MARKET (F) (G)			URBAN	MARG:	FRUIT
PREVIOUS CROP		SUSCEP:		NOT SUSCEP:		GRAM:	CRUC:	LEGUM:	UMBEL:	SOLAN:	CHENO:	OTHERS	NK
CROP GROWN IN DISTRICT				DOM:	ABUN:	COMM:	RARE	ACR'GE	—5	—10	—20	—50	+50
CROP DATA	PLANTING MONTH		PLOUGHING MONTH		PLANTING PERIOD			GROWTH AT VISIT			SHAPE OF FIELD		
					E	N	L	B.N.	N	A.N.	L + N	I. SQ:	I. OV:
APPLICATIONS	INSECTICIDES							WEED KILLERS			F. Y. M.		
	WINTER		SPRING		POST-BLOSSOM		NONE						
TO CROP								YES	NO	NK	YES	NO	NK
TO LAST CROP								YES	NO	NK	YES	NO	NK
AGE OF ORCHARD (YRS.)			—2	—5	—10	—20	+20	TREE TYPE		S	H-S	B	E
GENERAL TOPOGRAPHY		FLAT OR SLOPE	UNDUL	HILLY	MOUNT	SCARP	LOCAL TOPOGRAPHY			FLAT	VALLEY	SPUR	TOP
WOODED	NOT W						WOODED		NOT W				
FORM OF FIELD	W-M	FLAT	SLOPE	Hollow	SUMMIT	ALTIT.	BELOW S.L.:		—100	—300	—500	—1000	+1000
ASPECT	N	N.E.	E	S.E.	S	S.W.	W	N.W.	PROXIMITY TO COAST			—5M	+5M
SOIL CLASSIFICATION			CLAY	CLAY-LOAM		SILT-LOAM		LOAM	SANDY-LOAM		SAND	CHALK	PEAT
DRAINAGE	NK	V-POOR	POOR	GOOD	EXCESSIVE		STONES	NONE	GRAV:	S or S	S-O	S-1	S-2
SHELTER	MEAN HEDGE HEIGHT (FT.)				WALLS			TREES		WOODS		NONE	
NORTH	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
EAST	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
SOUTH	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
WEST	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
DAMAGE	NONE	SLIGHT CHECK		PATCHY	TOTAL FAILURE		POPULATION PER ACRE						
SPECIAL FEATURES CONTRIBUTING TO ATTACK													
WEED STATUS													
CULTIVATIONS													
REMARKS													

Fig. 3. Field questionnaire form used in pest surveys.

in 1953, in 24 counties, on commercial fields that had not been treated with insecticides. These estimates are, of course, subject to large errors, but it is abundantly clear that the Aphid was an important pest even in 1953, a year when it was not regarded as particularly serious by the farming community.

I would like now to say a few words about a subsidiary project on which we are engaged, and which has excited considerable interest. Since a large number of fields are visited annually in the course of various extensive surveys, we thought it would be a good idea to make a start at recording some of the permanent ecological features in each field that might influence plant growth and the peak density reached by the pests. We therefore drafted a field questionnaire (fig. 3), in which each of the " omnibus " terms used has been carefully defined. One of these forms is completed for every field visited, and even though the scheme has only been in operation for two seasons, we have already obtained some interesting results from it. It has, for instance, enabled us to show that, although the density of the cabbage Aphid is greater in areas in which brassicas are intensively grown that in areas in which they are grown only occasionally, it also tends to be greater on large fields than on small ones in both areas. We have also noted that, although sprouts tend to be grown on fields sheltered to some extent by hedges, over 90 per cent. of the fields without shelter of this kind carried very low Aphid populations. Again, information of this type is of considerable direct use to advisory entomologists, who can, with some confidence, tell farmers not to plant certain crops in situations at which pest densities tend to be high.

Finally, I would like to add a comment to the quotation with which Dr. Thomas opened his paper. It is relatively easy to measure the density of a pest in the field and express it in numbers. But knowledge of this sort is still of a " meagre and unsatisfactory kind " if the quantitative results cannot be interpreted and made use of with some confidence. That is why the Pest Assessment Committee devotes so much of its time to research projects designed to elucidate the " what " of plant and pest relationships. The " how " and the " why " we very sensibly leave to the professional insect and plant ecologists.

The Influence of *Lygus vosseleri* on Crop Loss of Cotton in Uganda

By Q. A. Geering
Empire Cotton Growing Corporation, Cotton Research Station, Uganda

The amount of crop loss caused by insects is more difficult to estimate if they damage the fruiting points of plants at an early stage of their development than if they attack the mature fruit. This has become particularly apparent where the Mirid, *Lygus vosseleri*, damages a plant such as cotton, when this is grown under the distinctive climatic conditions of the Buganda Province of Uganda.

Damage to cotton by *Lygus* has been recognised in Uganda since Hancock first described the symptoms in 1935 (1). Subsequent studies have produced some essential basic information on the biology and systematics of this Mirid (2–4), but little progress has been made towards determining its status as a pest on the peasant commercial crop.

Lygus attack is most easily noted by the torn and shredded leaves, and a leaf-damage index positively correlated with *Lygus* numbers has been developed to measure this. But the real damage is more apparent in the dead sympodial fruiting points killed by feeding activity. A severely attacked plant may also show gross structural deformity. One of the first problems tackled by the Cotton Research Station was therefore to develop a reliable method for controlling *Lygus* in the field, in order that this could be used to provide an estimate of its present importance as a pest (5). The work was started in 1951 by E. O. Pearson and K. S. McKinlay, and has now been handed on to our successors. A summary will be given of the results obtained to date.

McKinlay has already outlined the major development of the work during 1951–52 (6). This was the demonstration of the inadequacy of the usual layout of randomised plots of the order of 1 30 acre, for testing insecticide treatments for the control of *Lygus*. When DDT spray formulations, for example, were applied under these conditions, the total population of *Lygus* adults and nymphs was killed, but the population of adults on the unsprayed control plots also fell immediately, as they distributed themselves over the remainder of the experiment. Consequently, within 24 hours of spraying, there was only a very small difference in adult population detectable between the sprayed and unsprayed plots. The infestation develops by the arrival of immigrant adults over the whole of such an experiment; those arriving on the sprayed plots are killed by the residual deposit of DDT, and those on the controls are drained off by dispersal to the sprayed plots, where they too are killed. Thus, because of the mobility of the adults, the net result of repeated spraying of the treated plots at weekly intervals is to reduce the population over the whole experiment. The object of the experiment, to obtain cotton with the lowest possible *Lygus* infestation and compare this with cotton normally infested, is thus not achieved.

It had been hoped that if the size of the plots was increased to half an acre and the records were taken on their central portions, this effect of the mobility of adults might be largely overcome, but it proved impracticable to produce a sufficiently large area of uniform cotton for an experiment of this type.

In an earlier experiment to test the phytotoxicity of insecticide sprays, McKinlay had noted that single lengths of row (25 plants) sprayed weekly with DDT were largely free from leaf damage by *Lygus*, while plants in adjacent unsprayed rows were damaged severely. It was supposed that the spray deposit was acting as a repellant, and this was confirmed in the laboratory (7).

The design problem was solved in this instance, therefore, by weekly spraying with a DDT formulation of 50 ft. lengths of single rows, randomised in a block of cotton. Adults of *Lygus* were repelled from these rows to neighbouring rows of untreated cotton. For this method to be effective, the proportion of sprayed cotton must be small, and in the experiments to be described comprised 1/11 of the total area sampled.

In this way a more efficient though not yet perfect, comparison was obtained of the cropping of cotton protected from, and exposed to, *Lygus* attack. The same treatment and layout is adequate for protection from bollworm damage, which is sometimes important later in the season, since the resulting deposit remains to kill larvae of *Heliothis* and *Earias*.

A long-term experiment was therefore laid down, and was started in 1953. Its principal object was to contribute a seasonal estimate of the crop losses caused by insects to a co-operative study with the physiologists, pathologists, climatologists and agronomists of the causes of annual variations in yield. The experiment is repeated in three localities in the Research Station, separated by distances of 300, 1,000 and 1,100 yards. It entails spraying at 5–7 day intervals for varying periods throughout the season; for each period of spraying there were four replications of single rows of 25 plants. There are two sowings: one at the optimum time, in mid-June, which follows a bare fallow, and the other in mid-August, following a crop of early maize which has been grown on the first rains.

For the earlier sowing, the cropping season is divided into an early period (August and September) and a late period (October and November). In 1953, sprays were applied over both these periods, over each one separately, and over the three months from September to November. The early spraying was aimed primarily against *Lygus*; the later primarily against bollworm. In this season, however, the peak of *Lygus* attack occurred in October, and attack by *Heliothis* and *Earias* was extremely light, resulting for the whole season in only 2–3 flared squares per four plants. The main effect of spraying was therefore due to protecting the crop from *Lygus* attack at different periods.

The results in terms of yield showed that the range of response obtainable in different localities with the same degree of *Lygus* control is very wide. In none of the three areas did the complete spraying (17 applications at weekly intervals) give a significant increase in yield, though this treatment significantly reduced the *Lygus* leaf-damage index to 36–57 per cent. of the controls. In one of the three areas, however, a significant increase in final yield resulted from the spraying from September to November. The predominant effect of reduction in *Lygus* damage was to produce an earlier crop. Highly significant differences in yield were apparent in all areas at the seventh of the 13 picks, showing a significant negative correlation with leaf-damage index (r^2 for the three areas of per cent. yield at seventh pick and leaf-grade was 0·87, 0·52 and 0·75).

One could at this stage conjecture that where conditions result in a much shorter cropping season than in Buganda (the cropping season being probably a function of the different water-holding capacities of the different soil types), the effect of controlling *Lygus* on final yield might show the same sort of differences as emerged at the seventh pick of the June-sown cotton in this experiment. The August-sown cotton to a certain extent simulates these conditions, and in this season resulted in harvesting over a period of only seven weeks, compared with the 13 weeks of the earlier sowing.

On this late sowing, the shorter season was divided for spraying in the same way as before, but the periods were necessarily shorter. The continuous protection produced a significant increase in yield in only one of the three localities; the increase in this instance was equivalent to 512 lb. seed cotton per acre or 82 per cent. of the yield of the unsprayed cotton. In all localities, however, significant reductions were again effected in *Lygus* leaf-damage. In the other two localities, significant increases in yield were obtained by late spraying (in November) when the bulk of the *Lygus* attack developed on this later sowing. An earlier crop resulting from spraying was again apparent, but the unprotected plants did not compensate. Over all three localities there was a significant negative correlation ($r^2=0{\cdot}71$) between *Lygus* leaf-damage and final yield.

It would appear therefore that under the conditions of the Cotton Research Station, in this particular season:

(*a*) Only on the late-sown cotton could consistent yield increases be obtained by controlling *Lygus*. Complete control was not, however, achieved on either early or late-sown cotton, and the best treatment only reduced the *Lygus* leaf-damage index to 36 per cent. of the controls.

(*b*) There may be some significance in the fact that the maximum protection did not necessarily give maximum increases in yield. It appears that some insect damage early in the crop's life may be beneficial. Workers in America (8) have shown that early loss of fruiting points under favourable climatic conditions can actually increase yields of cotton.

We may note here that the late-sown cotton, being adjacent to the earlier sowing, probably suffered a heavier attack by *Lygus* than it would have if grown separately. This resulted from the continuous breeding of *Lygus* throughout the season, a feature that earlier work by Taylor suggests is abnormal in Buganda (2). The duration and intensity of attack was, however, still less than on the earlier sowing. This greater effect of the smaller attack indicates the detrimental effect of a shorter season resulting from late-sowing. The variety of cotton used has, however, been selected primarily for the longer season—and in this respect also the effect of *Lygus* would be accentuated. At Serere, in the Eastern Province of Uganda, where a different variety is grown to suit the shorter season, Mr. A. P. G. Michelmore has been repeating this experiment. With his permission I can state that his results have been similar to ours. Even there, with less favourable cropping conditions, in this year early protection from *Lygus* was not as beneficial as later protection from *Lygus* and bollworms.

These results will, it is hoped, have shown how difficult it is to obtain a ready estimate of the amount of crop loss caused by *Lygus*. The approach being adopted is to use insecticides as a tool for measuring losses, and it is fortunate that the experimental design is effective for both *Lygus* and the bollworms involved.

We have again in Uganda a complex of insects attacking the cotton crop: since these are not necessarily separated in time, it will not be possible always to estimate their separate effects. Under these conditions, the problem is reduced to studying the loss of fruiting points at different periods of the season, and to determining which losses are critical, and which insects are responsible. Three seasons at the Cotton Research Station have shown variations in level of bollworm attack, and timing of *Lygus* attack. It appears from the experiments just described that, provided the cotton is sown sufficiently early, the overriding ecological factors of climate and cropping season can determine whether *Lygus* damage will cause real loss of crop. One cannot draw any further conclusions until experiments of this type have been repeated, basically unchanged, over a number of years, in order to cover the widest range of both climatic conditions and levels of insect attack. Only then will it be possible to give a measure of the actual losses due to insect damage: *i.e.* how much, how often. In addition, however, the marked effect of locality is apparent even within the limits of a research station. How much more important, therefore, it is to take this into account when the situation under the peasant farming conditions is considered. It is a dangerous assumption that, because a particular insect or group of insects has been shown to be a serious pest on experimental stations, it must therefore be serious wherever it occurs on peasant holdings. Until standardised experiments of this sort are conducted on peasant crops over a number of years in many representative localities, one will not know the answer to the question, " How much loss, how often, in how many places ? " Such projects would take time and cost a great deal in terms of personnel and equipment. But until they are carried out, the true status of this type of insect pest and indeed of most others in African peasant agriculture will remain in the realm of speculation.

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Discussion

Mr. G. Ordish said that the immense value of the assessment of the damage caused by a pest led to a further step, the calling in of the agricultural economist. If, for instance, a treatment prevented the loss of 15 per cent. of the crop of brussels sprouts, a large surplus of brussels sprouts could arise. This would need to be avoided by the use of alternative crops, an easy matter in Britain where food-crops do not supply the demand. Assessment of damage by pests could also avoid unnecessary application of insecticides.

Prof. O. W. Richards pointed out that, if a pest was controlled in order to assess the damage it caused, it was essential that the treatment adopted should not control other pests on the plots. If it did, a useful figure might be obtained, but it would not be the one sought. He also stressed the necessity that the pest concerned should be correctly identified.

Mr. A. D. Pickett considered that it was dangerous to use an insecticide to assess the increase in crop production that resulted from the control of any given pest, unless the cumulative effect of the insecticide was ascertained, as it might directly or indirectly influence the status of many other species. He was reminded of attempts made to assess the value of sprays in the control of apple insects. In a large co-operative test involving a number of separate experiments, it was laid down that each treatment should have eight single-tree replicates. This made it possible to make very accurate statistical analysis and to draw very pretty graphs, but in his estimation these were not worth the paper on which they were printed. The figures had no validity, because the dynamic nature of the environment was not taken into consideration. While every reasonable effort should be made to improve methods of estimating damage to crops by pests, this object would be defeated unless it was ensured that all the many factors involved were taken into consideration.

Mr. J. M. Holborn asked for data on the estimation of real losses caused by pests of stored food products, but Mr. Herford said that he would deal with this point in the discussion on pests of stored products.

Dr. G. A. Patel said that the problem of real losses by insects had much significance in national planning in India, where the likely yield of certain crops was a matter of great concern. The Indian Council of Agricultural Research had taken up this work for the sorghum stem-borer (*Chilo zonellus*). From the initial survey data, the statisticians were of the opinion that some special method of analysis was required, as many of the observations would not record any infestations, and that this aspect had to be looked into first. It was also considered essential to determine the minimum measure or unit necessary for accurate data. Only after this had been done would it be possible to begin to study the effect of the pest on yield on a national scale, which would be a much more complicated thing to determine.

Dr. Taskhir Ahmad pointed out that present methods of assessing the relation between the abundance of a pest and the damage it causes varied with the different kinds of insects and plants. One single reliable method was required if different species were to be compared. The common practice of recording the abundance of an insect in terms of numbers per unit area of field did not in itself afford evidence of the damage it was likely to cause, because this depended also on the size and condition of the plants. Thus, a population of ten crickets per sq. yard could cause very serious loss on a germinating cotton crop, whereas one five times as dense might not cause noticeable injury to full-grown cotton. It would seem, therefore, that the number of insects per unit area of leaf surface on the plant would be a better guide to the importance of an infestation, though this would also be affected by the climatic conditions at the time.

Mr. STRICKLAND referred further to some of the experiments he had already mentioned to illustrate the risk that an insecticide used to control the pest under study may affect the crop in other ways. The use of TEPP in the experiments with the cabbage aphis was discontinued for two reasons. The first was that it also destroyed cabbage caterpillars, whereas attempts to eliminate them from the control plots by hand-picking were unsuccessful; and the second was that it appeared to stimulate the growth of the plants, so that the yields were higher than they should have been early in the season and lower later. In recent work on the frit fly, sprays of DDT and BHC were applied eight times during the season, and a small depression in yield occurred on the BHC plots. He asked Mr. Geering whether he had observed evidence of plant stimulation or yield depression of cotton sprayed with DDT.

Mr. GEERING replied that the spray was applied at double strength in greenhouse experiments, and no evident morphological difference in the plants resulted. It was possible in the field, however, that the yield was reduced if the plants were protected from " pruning " at an early stage, as it had been shown in the United States that the yield of cotton was increased by disbudding at an early stage of its growth if climatic conditions were favourable.

The CHAIRMAN said that he was filled with admiration for a country that provided the staff and facilities for long-term investigations of the kind described by Mr. Strickland. Assessment of damage by pests was a recent study, and much care and a great deal of work would be needed in its development. A sense of proportion should, however, be maintained, so that information was obtained only if it was wanted. Pests could be considered in three classes. Those of the first were so injurious that no assessment was needed; they were exemplified by the Kenya coffee mealybug or the coconut Coreid, which took the whole crop, or the coconut rhinoceros beetle, which actually destroyed the palms. Those of the second, which comprised many insects, were less injurious, so that assessment was desirable to determine if and when insecticides should be applied against them. Those of the third (of which he could not cite examples) were insects that fed on the plants but did not affect the crop from them.

DISCUSSION ON THE BIOLOGICAL CONTROL OF INSECT PESTS

Chairman: Professor O. W. Richards, *Department of Zoology and Applied Entomology, Imperial College of Science and Technology, London*

The CHAIRMAN said that agriculture could be described as an interference with the balance of nature. Previous meetings had shown how matters could be rectified by the use of chemicals; the present one was concerned with biological methods. The Commonwealth Parasite Service was formerly situated in this country, but it had since moved to Canada. The opening paper was by its Director, who would tell them something about it and about its recent work.

Biological Control Work on Cedar Scales in Bermuda

By W. R. Thompson
Commonwealth Institute of Biological Control

The work of the Commonwealth Institute of Biological Control is the subject of a separate report,* but I would recall here that it consists in the main of the collection of parasites and predators of various insect pests and weeds and their supply to the Government entomologists of Commonwealth countries. During recent years, however, the Institute has been asked by small colonies without adequate entomological staffs, not merely to supply parasite material, but to carry out complete operations on biological control. The most important of these has been an attempt to effect biological control of two scale insects attacking the native juniper or so-called Bermuda cedar in Bermuda. The Institute has been engaged on it, in co-operation with the Department of Agriculture of Bermuda, for about seven years, and I have thought that the entomologists attending the Conference would be interested in a brief account of the operations and results to date, though a good many already know something about it.

The Colony of Bermuda, which lies some 600 miles east of Cape Hatteras, consists of a hook-shaped island about 20 miles long by about 1½ miles wide, surrounded by a number of smaller ones. The island is composed of porous aeolian limestone which crops out all over the place, the average depth of soil being six inches. There are no streams, ponds or springs of fresh water. The climate is mild, humid and windy. The fauna is meagre and so, originally, was the flora, but many tropical and subtropical plants, shrubs and trees have been introduced, so that the vegetation is now very varied and interesting. However, the dominant species, which not so long ago constituted a practically continuous forest cover, is the Bermuda cedar (*Juniperus bermudiana*), which is allied to the North American red cedar but is quite different in form. While the North American red cedar is prostrate or conical, the Bermuda cedar heads out to form a fine shade stree. It is peculiar to Bermuda and has always been highly prized by the islanders. The characteristic beauty of Bermuda was, in the past, largely due to its cedar forests.

Some years ago, probably around 1942, certain proprietors in Bermuda who wished to beautify their estates accidentally imported two Diaspine scales, *Carulaspis visci* (*carueli*) and *Lepidosaphes newsteadi*, probably on conifers from California. Both in due course adopted the Bermuda cedar as their host plant and developed unnoticed on it for a number of years. They are said to have been still localised to a few acres in 1945, but several square miles were infested by them in 1946 and it is probable that they were already thinly scattered over a much larger area—*Carulaspis*, indeed, over the whole island.

Both scales are lethal to the Bermuda cedar in even moderate infestations, *Lepidosaphes* being so at a remarkably low density, and the mortality of the trees was already considerable in 1946. Bermuda subsists almost entirely on the tourist trade, and it was thought that the loss of natural beauty consequent on the extermination of the cedar forest would be a most serious matter for the economy of the island.

We were asked to take charge of the Bermuda project at the end of 1946. With the help of Dr. J. M. Waterston, who had already accumulated much valuable information about cedar pests, my wife and I began a survey of the infestation and parasitism in January 1947. In that season, *Lepidosaphes* was inactive, while *Carulaspis* was reproducing, though slowly. An Aphelinid parasite, *Aspidiotiphagus lounsburyi*, apparently introduced with the scales, was abundant all over the island, even in infestations of low density, and several other Aphelinids were also present, though much less common. Parasitism of 80–90 per cent. was frequently observed.

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* Appendix II, pp. 22–26.

From the rearing boxes, the emergence of parasite adults was always much greater than that of male scales, and sometimes even 10–15 times as great. Since the parasites exist only as females, these figures should give a fair idea of the relative proportions of host and parasite populations in the field. The parasites are active throughout the winter. The impression gained was that the parasite population was rapidly building up at the expense of *Carulaspis* and would probably bring it under control before very long. *Lepidosaphes*, though it spread slowly, was considered to be potentially the greater menace, since it was seldom parasitised and is lethal at a very low density.

Nevertheless, in view of the danger of the infestation for Bermuda, it was decided to import additional natural enemies. It was thought best to concentrate on Diaspine-feeding Coccinellids, since no species with this habit had been found in the survey or even recorded from Bermuda. With the help of friends and colleagues in Canada, California, the West Indies, Italy and Mauritius, large importations of material were rapidly organised. By the end of June 1947, when we were obliged to return to Canada, some 30,000 parasites and predators, including the predacious mite, *Hemisarcoptes malus*, the Aphelinid, *Aphytis mytilaspidis*, and a dozen species of Coccinellids, had been imported and distributed. Tests showed that four or five species of the Coccinellids could feed and reproduce on the scale, and there were indications that the Australian *Lindorus lophanthae* was becoming established in the field. At this point, the situation seemed promising. Dr. G. C. Ullyett, brought from South Africa for the purpose, continued the survey work during July and August and reported a continuous high parasitism and the more frequent appearance of *Lindorus lophanthae* in the field.

In October 1947, however, a severe hurricane struck Bermuda, causing extensive defoliation, burning of foliage by salt spray and other damage to the vegetation. At the request of the Bermuda Government, several visits were made to the colony during the winter of 1947 and the spring of 1948. These surveys indicated a rather less severe infestation and a definite spread and build up of the *Lindorus* population, but also an extension of the *Carulaspis* infestation to the whole of the island, as well as a marked fall in parasitism. No imported Coccinellids other than *Lindorus* were found in the field. From March 1948 onward, therefore, additional importations were made. During 1948 these comprised some 44,000 Coccinellids belonging to 13 species, of which seven had not previously been imported, and large numbers of the mite, *Hemisarcoptes malus*. Studies made during the summer and autumn by Mr. Bedford, who joined the Bermuda service as Government Pathologist in May 1948, indicated a steady increase in *Lindorus* and the establishment of one or two of the other Coccinellids. However, no evidence could be found of the establishment of species other than *Lindorus* from the 1947 introductions, though, as I have said, a number of these were actually able to feed and reproduce on *Carulaspis*. Furthermore, parasitism remained low, though there seemed to be a general reduction in infestation and in cedar mortality, and some evidence of recovery of cedars.

Unfortunately, in October and November 1948, three more hurricanes, one of exceptional severity, struck the island. Large sections of the cedar forest, particularly in the areas exposed to the wind and salt spray, were severely burned and defoliated, even though they were free from scale. The loss of foliage from infested trees was, naturally, even more serious.

At the urgent request of the Bermuda Government, I visited the island, accompanied by Mr. W. F. Sellers, in December 1948. It was found that the condition of the cedar forests had considerably worsened. Most of the new and severe damage was due to the hurricane; but it was also evident that *Carulaspis* was not yet under control, though *Lepidosaphes* had subsided. I may say that the reasons for the decline of *Lepidosaphes* are not entirely clear. It may possibly be due to the combined effect of the mite, *Hemisarcoptes*, and a curious fungus of the genus *Myriophagus*, probably introduced from Canada with *Hemisarcoptes* from *Lepidosaphes ulmi*.

However, what eventually happened was that *Carulaspis* swept through the forest like a tide, killing off all the trees bearing *Lepidosaphes*, which is now practically non-existent. In this rather grim way the biological control of *Lepidosaphes* was effected.

Lindorus lophanthae was found to be abundant almost all over the island. However, since the Bermuda authorities were determined to save their trees if this is possible, it was decided to organise a mass-breeding programme in California, in a laboratory specially constructed for the purpose. Mr. W. F. Sellers was placed in charge of this work. Through his energetic efforts, an excellent though inexpensive laboratory was erected in Fontana about seven miles from Riverside. In 1949-50, Mr. Sellers reared and shipped to Bermuda over 700,000 Coccinellids, representing nine promising Diaspine-feeding species. In the meantime, the Agricultural Station in Bermuda was rebuilt, so that a fine entomological laboratory is now available there. The Government Pathologist, using the methods adopted by Mr. Sellers, reared an additional 75,000 ladybirds in this laboratory. A survey made in November 1949 indicated that at least two species in addition to *Lindorus* had become established in the field. The breeding, introduction and distribution of Coccinellids was continued until the end of 1951 and was then stopped. At that time, several of the small Coccinellids imported from California seemed to be established. During the four or five years of work, a search was made in various parts of Europe, North Africa and the Canaries for native parasites and predators of *Carulaspis*, *Lepidosaphes* and related scales, and some of these were introduced in fair numbers, but they did not become established. I have not attempted for this paper to get the exact total of parasitic and predacious species and individuals introduced into Bermuda. I believe, however, that we brought in at least a million and a half individuals, representing some 40 species of Chalcidoids, Coccinellids and Nitidulids, as well as the predacious Acarid, *Hemisarcoptes*. Eventually, however, only *Microweisia suturalis* and *Lindorus lophanthae* persisted and multiplied.

In spite of the great efforts made and the relatively rapid increase of one of the introduced predators, the devastation of the cedar forest proceeded very rapidly. In the summer of 1946 an area about four miles long in the middle of the island was already infested. The infestation moved with the prevailing winds, which are from the west, more rapidly than against them. By the end of 1947, *Carulaspis* had extended its range right to the eastern extremity of the island and almost to the western extremity. By the end of 1948, practically the whole island was infested, though the intensity of the infestation was less in the western than in the eastern end. A good many of the trees were dead in the middle of the island in the summer of 1947. The hurricane in the autumn of that year injured many trees and undoubtedly had its most severe effect on those that were fairly heavily infested. The hurricanes of 1948 combined with the increasing scale population to damage a great part of the forest. By November 1950, 75 per cent. of the Bermuda cedars were dead. Large stands of trees in good condition still remained in the western end of the island, comprising the parishes of Southampton and Sandys, but these stands declined in subsequent years, though much more slowly than the stands that declined before the introduction of *Lindorus lophanthae*. However, healthy or reasonably healthy trees of all ages still existed in all parts of the island even in the summer of 1953, and large groups of these trees could be found in some areas, for example on Paget Island and on Hawkins in the Great Sound. My impression last summer was that the new growth and the seedling trees were persisting better than they did in the early stages of the infestation.

To sum up the results of the work, it must be said that it failed in its main objective, which was the preservation of the cedar forest of Bermuda. On the other hand, it was not entirely unsuccessful, since stands of healthy trees and isolated healthy trees are still scattered here and there all over the island, and this, I think, can be safely attributed in part at least to the work of the parasites and predators, since infested trees died far more rapidly before their introduction than they do at the present time and practically none persisted in the heavily infested areas. It is worth noting also that the second Coccinellid established, *Microweisia suturalis*, seems to be a good deal more active and abundant than *Lindorus lophanthae*, but is not yet common over a great part of the island. When it reaches its maximum efficiency, the results may improve. There is no doubt whatever that many trees now declining will die within a few years. Nevertheless, the possibility that the Bermuda cedar will be completely exterminated, as I feared at one time that it would be, now seems remote.

As an experiment in biological control, this problem has been intensely interesting. It is unfortunate that pressure of work on the staffs of the Institute and of the Department of Agriculture in Bermuda has made it impossible to follow the course of events as accurately as could be desired. Nevertheless, some lessons have been learned.

The first, which is of considerable importance, is that predators as well as parasites may be highly specific in their host relations. Of some 30–35 species introduced, only two have become satisfactorily established in Bermuda on *Carulaspis visci* on the Bermuda cedar. A species of the genus *Telsimia* curiously enough bred freely in the field for one or two generations and then died out. Species found feeding on *Carulaspis visci* in other parts of the world did not usually become established in Bermuda. *Lindorus lophanthae*, the first successful species, was not obtained feeding on cedar scale but on scales attacking *Citrus* in California. A number of species that reproduced in quite a promising manner on the cedar scale when confined in bags with infested branches in the open were never recovered from field liberations.

Although very large numbers of certain predators were introduced during successive years and the cedar scales constituted by far the most important source of food for them on the island, no adaptation to life on the cedar scale ever occurred. One might have expected that there might be mutations originating races capable of developing on the cedar scale, but in fact the colonies placed on the cedars slowly disappeared and the species liberated apparently became extinct. On the other hand *Lindorus lophanthae* and *Microweisia suturalis*, though bred for many generations in the laboratory on other Diaspine scales grown on potatoes, readily attacked the cedar scale when liberated in the field. The parasites and predators that became established in the island seem, as I have said, to be very specific in their host relations. Both Chalcidoids and Coccinellids were found commonly on the lightest infestations. This fact led us to hope that, after the death of large sections of forest heavily infested by scale and carrying at one time very large populations of parasites and predators, these parasites and predators would move *en masse* to the scale-infested live trees and reduce the infestation to a negligible level. Nothing of the kind occurred. So far as we could make out, the Coccinellids simply died on the trees killed by the scales. In 1953, in order to determine the importance of the dominant parasites, we collected samples of infested cedar branches from all over the island and reared parasites and male scales from them. The most important finding was that the number of male scales that emerged in the rearing boxes was about three times as great as the number of parasites. In fact, 2,008 male scales emerged as against 752 parasites, the latter belonging for the most part to the genus *Aspidiotiphagus*. In 1947 on the other hand, the number of male scales that emerged in the rearing boxes was, in a large sample, only half as great as the number of parasites. In actual numbers, we obtained 18,271 parasites and 9,088 male scales during that year. This result showed that, although the scale population in the island had fallen enormously owing to the death of the majority of the trees on which the scales were living, the parasites did not tend to concentrate on the remaining scales by moving from the dead trees to the live ones as might have been expected, but actually declined in importance. In other words, the increasing scarcity of the scale owing to the death of the trees resulted in an increasing scarcity and therefore in a lower effectiveness of the parasites.

During the 1947 survey, as I have said, the parasites were extremely abundant and appeared to be killing off at least 75 per cent. of the scales. This led us to hope that they would be able to reduce the infestation below the point of economic damage in a relatively short time. This did not happen. On the contrary, the infestation became steadily more severe and more extensive, and the trees continued to die. This was no doubt due partly to the fact that the scale is not killed until it is full-grown and has done its damage, and partly to the fact that even parasitised scales produce in many cases a fair number of eggs. Nevertheless, the ineffectiveness of the parasites was disappointing and surprising.

As is well known, some of the most striking successes in biological control work have been obtained on islands. This led the late Dr. Imms to suggest that islands, because of their insular character, are likely to be particularly favourable for biological control operations. Bermuda is an island and a very isolated island, but this feature did not seem to be advantageous, though the small size and isolation of the area of course facilitated investigations. It seems possible indeed that the failure of the operation has a roundabout connection with the fact that Bermuda is an island. A comparison with infestations of juniper by *Carulaspis* on the American mainland suggests that the Bermuda cedar itself is a mutant that has been able to persist until recent years precisely because of the isolation of Bermuda and the freedom of the cedar forest from insect infestations. Junipers on the American mainland do not in fact suffer particularly from attack by *Carulaspis visci* though it is sometimes quite common. The Bermuda cedar on the contrary seems to be excessively susceptible. Its susceptibility is not, however, uniform. Every heavily infested cedar dies eventually, but some cedars never acquire a really severe infestation. It seems, therefore, that in many cases the parasites and predators have brought the infestation below the lethal level, so that many trees now survive that would have been killed before the introduction of *Lindorus* and *Microweisia*. My impression is that the trees infested in the central area of the island before the introduction of these predators practically all died, whereas a good many of the trees infested subsequently now survive. A final point that emerged from this work, and has also of course been demonstrated very strikingly in the work of the Californian entomologists on scale parasites, is that two parasites morphologically very similar may behave very differently. On the Bermuda scale we find two species of *Aspidiotiphagus*, *A. citrinus* and *A. lounsburyi*, that show only an extremely slight difference in morphology, but an enormous difference in effectiveness. In fact, in rearing work, we obtained thousands of adults of *lounsburyi* to two or three of *citrinus*. As you know, the Californian work has demonstrated a marked difference in behaviour and specificity between forms that are, at present at least, morphologically inseparable.

As you will readily realise, the points I have mentioned in discussing the Bermuda work are for the most part problems requiring solution. They indicate how far we still are from understanding the results of the empirical experiments we carry out in this field. It is only if we obtain the financial resources and the scientific teams necessary to follow our experiments in detail by the careful and continuous collection of field data and the interpretation of the data by laboratory investigations, that we will have any hope of putting our biological control work on a scientific basis. This is the only way in which we can hope to make it a satisfactorily practical operation.

Discussion

Mr. A. B. BAIRD said that a point of particular interest that was brought out in the paper and was being realised more and more was the specificity of predators. This had been observed also in Canada. Work on biological control there was increasing, as shown in the review of Canadian work [see Appendix VI, pp. 42–45], and great importance was attached to it.

Dr. T. H. C. TAYLOR said that he had long wanted to hear details of the interesting and complicated campaign in Bermuda. Everyone realised that it was an unusual case; he would certainly have expected that the insular conditions would have been eminently suited to biological control, but this method had not entirely succeeded, in spite of most careful work. Turning to more general aspects, he recalled that, discussing biological control with a few interested entomologists at the Amsterdam Conference, he had shown himself not entirely in sympathy with a proposal to set up an international organisation for biological control in Europe, because he had not thought the prospect of success sufficient to justify it. He had been thought pessimistic, but he had merely been trying to be realistic. He still felt in general terms that too much should not be expected from biological control. There would certainly be cases in which it would be entirely successful, but he felt that they would be exceptional. He would like Dr. Thompson to give his views on the future of biological control in general.

Dr. THOMPSON replied that he agreed, on the whole, with Dr. Taylor. Biological control was not, and should not be, regarded as a panacea. There were many cases in which there was little or no evidence that natural enemies were of significance in reducing the damage caused by a pest. In general, biological control operations were a long shot. One thing, however, should be pointed out and this was the finding by Dr. Massee and Mr. Pickett in controlled experiments that the destruction by sprays of previously overlooked natural enemies resulted in outbreaks of pests. This served as a demonstration of the rôle of indigenous natural enemies, and it also provided evidence that the effects of introduced natural enemies might not be negligible even when they were not spectacular.

Dr. J. M. WATERSTON said that the hypersensitive reaction of the Bermuda cedar (*Juniperus bermudiana*) to the toxic effects of *Carulaspis visci* and *Lepidosaphes newsteadi* was almost certainly the major factor that contributed to the very rapid loss of the trees before biological control could be efficiently tested and established. It was noteworthy that the foliage of the introduced species of juniper present in Bermuda at the time (*J. barbadensis*, *J. silicicola* and *J. virginiana*) did not suffer damage from the infestation and *J. barbadensis* actually discouraged the build-up of the scale. Less than 1 per cent. of the original stand of *J. bermudiana* remained to-day, but some of the surviving trees had shown a high tolerance to *C. visci* over a nine-year period of observation, and this tolerance appeared to be inherited in their progeny. A factor that possibly accounted for the paucity of the Coccinellid fauna in Bermuda and made it so difficult to establish further species there was the presence of the ant, *Pheidole megacephala*, which infested the cedar trees and preyed on the larvae.

Bermuda could supply one example of successful biological control that might not be well known. Oleanders, which provide the most important hedge plant and windbreak in the Colony and are the main feature in the re-afforestation programme there, were threatened with extinction some thirty years ago by the introduced West Indian peach scale, *Pseudaulacaspis pentagona*. This scale, first observed in Bermuda in 1917, was established over a wide area by 1920, being present on 27 different host plants and killing many oleanders. No parasites or predators were observed at the time. In 1921, Prof. Whetzel introduced *Prospaltella berlesei* and *Aphytis diaspidis* from Italy. *A. diaspidis* became rapidly established with spectacular results, evident control by it being obtained by 1923. Part of its success appeared to lie in its ability to survive under conditions of low host density. Small outbreaks of *Pseudaulacaspis pentagona* had afterwards occurred from time to time in Bermuda for reasons that were not clearly understood, but the pest had never increased as it had done prior to the introduction of *A. diaspidis*.

Dr. F. L. VANDERPLANK asked Dr. Thompson whether the Bermuda scales were attended by ants. He had found in Zanzibar that, if ants tending Coccids were prevented from reaching them, the Coccids became covered with honeydew and were soon smothered by the sooty mould that grew on it so that they died. Moreover, ant exclusion favoured the work of parasites and predators.

Dr. THOMPSON replied that he had carried out experiments in which the trees were kept free from ants by banding them with an insecticide, but little difference in the infestation by Coccids resulted. He pointed out in this connection that the Argentine ant had just arrived in Bermuda. It is known that exclusion of this species is of great importance in the control of mealybugs by *Cryptolaemus*.

Dr. R. H. LE PELLEY said that experience in Kenya provided no grounds for pessimism as regards the prospects of biological control. Successes there had been more frequent than failures and some had been spectacular.

Mr. B. B. GIVEN felt that a further aspect of the subject required mention. Most of the attempts to obtain biological control were made as a matter of expediency, and initial surveys, before the introduction of parasites and predators, were not carried out. For the evaluation of results, it was just as important to conduct surveys before liberation as after, but neither type of survey had been made in New Zealand in many cases in which natural enemies had been introduced. It was hoped in the near future, however, to obtain information on the position regarding introduced parasites and predators. He believed that failures to investigate fully the results of introductions had been due to one of two causes. Either the pest had not been important enough to make the introduction worth while, or the natural enemies had been so successful that further investigation had been thought unnecessary.

DISCUSSION ON THE BIOLOGICAL CONTROL OF WEEDS

Chairman: Mr. B. B. Given,
Department of Scientific and Industrial Research, New Zealand

The CHAIRMAN said that previous discussions had been concerned with phytophagous insects considered as pests. Fortunately, however, the habits that make insects injurious to plants could be turned to good account in the case of species that feed on plants that are pests. Phytophagous insects could be used to control weeds, and their effectiveness in controlling weeds was sometimes spectacular. Very little had been written or said of the general nature of the underlying principles of their use, but this was the subject of a paper written by Mr. Williams, of the Department of Agriculture, Mauritius, and he called on Dr. R. Mamet to read it.

The Biological Control of Weeds

By J. R. Williams
Department of Agriculture, Mauritius

Wild plants may be regarded as weeds for economic or aesthetic reasons, or for both, and a weed problem may result from many species growing in association, or from the growth of a few, or even one, species. Important weeds may, for the purpose of this discussion, be placed in one of two categories. The first contains the weeds that form part of the long established flora of a country and are noxious plants because they quickly invade cultivated land or because they are undesirable on semi-cultivated areas such as grazing land. Here the problem is essentially a consequence of maintaining the flora in an artificial state for agricultural or other reasons. In the second category are plants that are alien to a country and exhibit a far greater reproductive and competitive capacity than they do in their countries of origin, where they may not be considered noxious plants. Such weeds present a special problem, for they are primarily important, not on cultivated land, where weed control is necessarily a routine measure, but on land occupied by natural or semi-natural vegetation, where control by normal methods is either difficult or impossible. The established natural succession of vegetation may be upset by these weeds, with dense growths forming at the expense of useful or more desirable plants.

The theory that underlies the biological control of weeds is relatively simple and is applicable only to alien weeds. It postulates that the great increase of reproductive rate and vegetative vigour that a plant may show after its introduction into a country is due primarily to a lack of natural enemies, implying that in its native country its comparatively innocuous status is maintained by such enemies. It seems probable that this is always true when an alien weed grows to great excess, for while the other factors that regulate plant growth (*e.g.* soil conditions, climate or the competition of other plants) may be different and perhaps comparatively favourable, they will nevertheless be operative as restricting agents. In other words, the more excessive the growth of an introduced weed, the more likely is the cause to be an absence of natural enemies, and the chances of controlling it biologically are correspondingly higher.

In practice, the biological control of a weed involves the transfer of its insect enemies from regions in which it is indigenous to the country in which it has become a pest. The use of other phytophagous organisms does not seem practicable. Species that will not harm useful plants are selected, and care is taken to exclude their natural enemies, so that their phytophagous activity is intensified in their new environment. In this manner, an insect-plant balance may be created that is adverse to the plant but does not resemble that existing in its country of origin, since it depends upon the intensified activity of a few, or even one, species. The objective is to create biotic factors adverse to the weed and not to simulate its previous adverse biotic environment. It is in this light that the utility of the method and its results should be viewed, for, on the one hand, insects that do little harm to a plant in its native country may be eminently successful control agents (*e.g. Schematiza cordiae* with *Cordia macrostachya*, and *Liothrips urichi* with *Clidemia hirta*), while, on the other hand, the presence of one or a very few important controlling insects is not likely to give such a uniform and stable control as occurs in the country of origin of the weed.

The critical phase of biological control work against weeds is the selection of species that will not harm other plants, or at least not useful plants. All other considerations are subordinate, and a suitable species for introduction into a country against a weed is one that is safe to introduce, irrespective of its other characteristics.

The danger to other plants when a phytophagous insect, freed of its parasites and predators, is used for weed control lies (*a*) with the reliability of the methods used to determine its host-plant relationships, and (*b*) with the possibility that the insect may change its normal host-plant relationships owing to new environmental conditions.

Let us consider first the methods that are employed to determine host-plant relationships. These comprise field observations in the insect's natural habitat, laboratory tests with a variety of plants, and consideration of any specialised features shown by the insect that evidently restrict its choice of food-plant. In addition, circumstantial evidence may be provided by the botanical nature of the weed and by the known habits of related species.

Field observations serve chiefly as a guide and as a check to more critical methods of assessing host-plant affinities. Most works on weed control emphasise starvation and preference tests in the country of origin of the insect and again in the country in which its release is desired. Occasionally, however, an insect may be so highly specialised that tests are unnecessary — as with *Eurytoma* sp., which was introduced into Mauritius from Trinidad against *Cordia macrostachya*. No tests for specificity were made with this insect, for it is a seed-infesting species with a life-cycle closely adapted to the structure and maturation changes of the fruits of its host plant. But with the great majority of phytophagous insects, the observable relation between plant and insect is not sufficiently intimate to serve as evidence of specificity, and tests of some kind are essential. What form should they take and what data must they provide to show clearly that an insect is safely restricted to certain plants ?

An insect that is believed to be specific from field data may feed to a varying extent upon other plants during starvation tests, depending upon the conditions under which the tests are performed. The leaf-eating beetle, *Schematiza cordiae*, was tested in the orthodox manner by starvation tests in both Trinidad and Mauritius before its release in the latter country against *Cordia macrostachya*. When it was confined in petri dishes, slight feeding upon several unrelated plants occurred, while appreciable feeding occurred upon the weed and its close allies and also, surprisingly, upon cabbage. When confined in cages, the starved insects would never feed upon cabbage. The life-cycle could be completed only upon the weed, and the insect was eventually released. Similar examples are available from the Australian work against prickly pear; for example, *Cactoblastis cactorum* was able to feed and sustain itself for some days upon tomato fruits. The Australian policy was to consider a significant starvation test as one where the life-cycle could be completed on a plant other than the weed itself, and to disregard temporary feeding unless it seemed of a dangerously intense nature. This seems a reasonable basis upon which to work, but much obviously depends upon technique, which should be varied to give as wide a picture as possible of reaction under abnormal experimental conditions. The data obtained has then to be considered in conjunction with the observed behaviour in nature, the botanical isolation of the weed, the value of related plants, and any other information that seems to have a bearing upon the advisability of releasing the insect. The greatest weight should, however, rest with the evidence concerning the ability of the insect to develop upon plants other than the weed.

Upon the release of a phytophagous insect possessing certain known feeding habits, what are the chances of a change of behaviour, with possible harmful consequences as a result of the new conditions to which it will be exposed ? There are many examples of the presence within insect species of races or strains with different host-plant affinities, and with some insects it has been possible to produce such strains experimentally; but, while it is acknowledged that host range is liable to alter with the appearance of new races, it should also be remembered that constancy of habits and stability of a species is the rule and not the exception, unless the viewpoint is evolutionary. When phytophagous insects are used for weed control, the question is really whether the acute food shortages that may result if the weed is being successfully eradicated are liable to induce new host-plant affinities by selection from a very large field population. There do not seem to be any other environmental influences that would favour a change of feeding habits. Provided that the precautionary investigation has eliminated insects that could develop on plants to which they are normally averse, the released insects are those that are physiologically unable to develop, or to sustain themselves for any length of time, upon any plant but the weed, or perhaps the weed and a few unimportant related plants. To be instrumental in the formation of a new strain with different feeding habits, selection must therefore overcome not the insect's preferences or specificity due to sensory perception, but its physiological inability to utilise certain plants as food. In conjunction with this, if conditions that favour severe selection are produced, they will not be of long duration, occurring only immediately subsequent to a rapid collapse of the weed.

The danger of using insects for weed control would thus appear to rest with the precision of the tests used to determine host-plant relations and not with the possible development of new strains within the species after its release has been effected. It is perhaps worth noting that this danger has not materialised to date, and it may be of interest to mention again the example of *Schematiza cordiae* in Mauritius, where huge beetle populations were left with inadequate food as a result of their own activity. The only plants other than the weed that were injured by the beetles were its near relatives, *Cordia myxa* and *C. abyssinica*, and although oviposition also occurred on them, larval development was never seen. These two species of *Cordia* are not very common in Mauritius, but nevertheless were available to large numbers of beetles. No predilection for them developed, and, now that the beetle populations have diminished, no feeding or oviposition is to be observed upon them.

The biological control of weeds is clearly a practice that involves more evident danger than does the biological control of insect pests. An error may result in direct and readily apparent harmful consequences. Less attention is given to the possibility that an introduced entomophagous insect may attack species other than the pest insect, since the other hosts it may find will usually be either harmful themselves or considered of no value if they live on plants from which no economic benefit is derived. Weed control demands that the host-relations of the insects employed are known with some precision, while this is not usually a necessity when using entomophagous insects. This is the essential difference between the use of phytophagous and entomophagous insects. It seems well to disregard apprehensions that phytophagous insects are less delicately adjusted to their hosts and are more likely to change their habits than are entomophagous insects.

In conclusion, while the control of weeds by insects is a technique that has given concrete, and sometimes remarkable, results in various parts of the world, its applicability to weed problems appears to be very restricted. This is partly due to the difficulty of employing phytophagous insects, but even should we agree that with proper precautions there is less hazard than has been formerly supposed, there still seems little scope for wider application of the method. With all weed problems to which the method has been applied in the past, the ecological scene has been fairly distinctive—excessive growth of an alien weed indicating the absence of an important limiting factor, and an assurance that eradication would not lead to its replacement by weeds equally or more undesirable. There is also little evidence that phytophagous insects are generally important as limiting factors in the economy of wild plants, as pointed out by Thompson nearly 25 years ago. It is for ecological reasons that the biological control of weeds will probably remain what it has been in the past—a most useful technique of limited applicability. It is true that the proportion of successes to failures in attempts to obtain biological control of weeds has been high—much higher than the proportion in attempts to obtain biological control of insects. Such a comparison, however, is not valid, for entomophagous species are often employed against an insect pest when there is no real evidence that natural enemies are at all important to its economy. The use of natural enemies against weeds, on the other hand, has never been lightly undertaken for reasons already discussed.

Discussion

Dr. W. R. THOMPSON thought that some of those present at the meeting might not be aware of the results obtained in the work on *Cordia macrostachya* in Mauritius, and asked Dr. Mamet to give an outline of them.

Dr. MAMET said that the work was carried out with the valuable aid of Dr. Simmonds, of the section of the Commonwealth Institute of Biological Control stationed in Trinidad. The first insect introduced and released against *Cordia macrostachya* in Mauritius was *Physonota alutacea*, a leaf-eating species, but it failed to establish itself. A second leaf-eating species, *Schematiza cordiae*, which had meanwhile been under investigation, was then introduced from Trinidad and released, after extensive feeding tests carried out both in Mauritius and Trinidad had been successfully concluded. This insect multiplied so quickly that thousands of individuals could commonly be found feeding greedily on *Cordia* leaves, and a spectacular decrease of the weed could be observed about a year after its release. It was noted, however, that the eradication of the weed by *Schematiza* was not so intense in the drier parts of the island (the south-western coastal belt) as in the other districts. A seed-infesting species, *Eurytoma* sp., was meanwhile introduced and released. As pointed out in the paper that had just been read, no feeding tests with this species were carried out, on account of its specific mode of life. It had now spread all over the island and was infesting between 50 and 70 per cent. of the seeds of *Cordia*.

Before these insects were introduced, *Cordia* covered the greater part of the few grazing areas of the Island and most of the semi-wild plantations of Mauritius hemp, as well as the patches of waste land that occurred here and there. As a result of the introduction of *Schematiza*, most of the grazing lands and a good part of the land under Mauritius hemp had now been practically freed of the weed. It was hoped that the combined effect of *Schematiza* and *Eurytoma* would reduce the density of *Cordia* in the western coastal belt of the island to a low level in two or three years and would also keep under control any recrudescence of the weed elsewhere.

Dr. W. F. JEPSON, speaking as one who had spent a number of years in Mauritius and well knew the magnitude of the problem of *Cordia* and other weeds under the conditions of high rainfall in the island, asked Dr. Mamet whether the tremendous upheaval of the plant ecology of the island that the suppression of *Cordia* must have caused had led to an increase of other species of weeds, such as *Lantana*, the other common woody weed in Mauritius.

Dr. MAMET replied that there had in fact been a recrudescence of *Lantana*, it seemed probable that measures for its control would eventually have to be considered.

Mr. W. ALLAN said that the replacement of *Cordia* by *Lantana* did not appear to have been on a very serious scale. It had occurred in a relatively limited area of high rainfall and temperature, more particularly in the region of the airport. Sugar estates had said, in reply to questions, that *Lantana* had not increased significantly since the suppression of *Cordia* and that it was not necessary to start a control campaign.

The economic effects of the destruction of *Cordia* had been considerable. The weed had suppressed and replaced the wild Mauritius hemp (*Furcraea*) from which fibre is extracted for the manufacture of sugar bags. Suppression of *Cordia* had allowed the recovery of Mauritius hemp over large areas and the greater output of fibre had been particularly welcome because of the shortage of jute. A second effect had been the restoration of grassland, allowing more fodder for the peasants' cows, on which the island's milk supply depends. A third had been the reduction of the labour force employed on some estates on which *Cordia* had been a pest.

Dr. E. S. Narayanan questioned the extent to which the control of weeds by biological methods would have a future in view of the recent discovery of a number of highly effective herbicides. The results of the biological control of cactus (*Opuntia*) in Australia had been spectacular, but he doubted whether similar success with any other weed had been obtained. In India, too, control of cactus (*Opuntia dillenii*) had been obtained over an area of some 100,000 acres by the introduction and establishment of *Dactylopius tomentosus* from Ceylon. *Lantana* was a serious problem in India, and he did not know whether biological control of *Lantana* had been achieved anywhere in the world. A Tingid (*Teleonemia*) that had been imported against it from Hawaii had not been released in India because experiments showed that it would feed on the inflorescences and leaves of teak.

Mr. I. F. B. Common said that when further work on the biological control of *Lantana* was being contemplated in Australia, its actual and potential status as a pest was considered in relation to its value as a plant that recolonises old banana lands. On the one hand, it was considered an important weed pest, particularly in the rain-forest areas, where it affected valuable dairying pastures. On the other hand, it had proved of value in preventing soil erosion in abandoned plantations of banana on the steeper rain-forest slopes, and had so restored the diminished soil fertility there that bananas could be replanted after a few years.

Mr. D. V. W. Abeygunawardena in reply to a question by Mr. Allan said that *Lantana* was not an important weed in Ceylon and, where it occurred, the usual practice was to dig up the plants. No system of biological control was adopted.

Dr. R. H. Le Pelley asked for information regarding what had been done in the biological control of *Lantana* in Australia, and whether any progress had been made in investigations on the possibility of introducing insects against *Heliotropium* there. He said that there were several species of *Heliotropium* in Kenya and they were attacked by several species of insects, including a Tingid bug, and a midge that infested the flower or seed heads. It was not known whether these insects were confined to the genus *Heliotropium*, but it might be worth while to investigate the possibility of their use against it.

Mr. Common replied that *Teleonemia* had been introduced into Australia for the control of *Lantana* some years ago. It had become established, but had not proved to be an efficient means of control. General surveys of its abundance and its effect on the plant had suggested that it was better suited to the higher rainfall areas of central and northern Queensland. Mr. F. Wilson had visited Europe and studied insects attacking *Heliotropium* in the Mediterranean area. He concluded that none of these insects could safely be introduced into Australia.

Mr. C. R. Wallace said that a species of *Lantana*, almost certainly *L. camara*, occurred in the coastal area of British Guiana, but was not an aggressive weed there, so that an investigation of insects infesting it might yield useful results. Referring to the point that the status of a weed as a pest might vary with the area, he remarked that *Tagetes glandulifera*, which is troublesome in northern New South Wales, is said to be prized as a soil renovator in India.

Prof. T. W. Kirkpatrick asked for an explanation of the fact that *Cactoblastis* had been much less successful in the control of *Opuntia* in South Africa than it had been in Australia.

Mr. C. C. Hattingh said that natural enemies were the main cause of lack of success of both *Cactoblastis* and *Dactylopius* in South Africa. *Cactoblastis* was destroyed by baboons and possibly fungi, and *Dactylopius* was attacked by predacious Coccinellids. *Cactoblastis* had, however, been successful in restricted areas.

Mr. K. P. LAMB referred to the widespread phenomenon of plant resistance to insect attack, and asked whether there was any evidence of the occurrence of varieties or races of weeds resistant to insects that normally attack the species to which they belong.

Dr. J. M. WATERSTON, commenting on this question, and on a query by Dr. Jepson regarding *Acanthospermum hispidum*, a most important weed in Northern Nigeria, said that it had been difficult to find any insect that would feed on this weed. Dr. Thompson might be able to say what were the latest findings of Dr. Lloyd, who had been searching on behalf of Nigeria for insects attacking it in South America.

Dr. THOMPSON replied that Dr. Lloyd had made an extensive survey of the weed in South America and found that it was extremely abundant, not only in cultivated, but also in uncultivated areas, and had no effective enemies.

DISCUSSION ON SOME PESTS OF TROPICAL CEREAL CROPS

Chairman: Mr. D. Rhind, O.B.E.,
Secretary for Colonial Agricultural Research, Colonial Office

The CHAIRMAN said that the insect pests of cereals in the tropics were of great importance, because these were the crops on which millions of people depended for their food. He hoped for much from the discussion, as the tropical countries were pretty well represented at the meeting. It would be opened by two papers, the first by Dr. Barnes, who, as they all knew, was a world authority on midges, and the second by Mr. Bowden, who had specialised on the study of stem borers in the Gold Coast for a number of years.

The Sorghum Midge Problem

By H. F. Barnes
Rothamsted Experimental Station

My memorandum on the gall midges living on the sorghums, the *Panicum* millets and rice* has already been circulated as one of the papers of this Conference, and I now want to provoke a discussion that will end, I hope, in all possible steps being taken to combat one of the most serious threats to the production of food in the tropics.

The sorghum midge (*Contarinia sorghicola*) was described from Texas (Coquillet, 1898) and has for many years been recognised as the most important insect attacking the grain sorghums in the United States. In the first issue of the Farmers' Bulletin on this midge (Gable, Baker & Woodruff, 1928), it was stated that its ravages on these crops, which had an annual farm value of about 100,000,000 dollars, amounted to millions of dollars every year. A yearly loss of approximately one-fifth of the crop was not unusual in some sections, and practically no grain was produced in them in years particularly favourable to the midge. These statements were not contradicted by Walter (1941 *a*) when he revised the bulletin. Similar reports of the great damage that the sorghum midge does to grain crops have come from the Anglo-Egyptian Sudan (Cowland, 1936), where a loss of 25 per cent. is not uncommon, and from Queensland, Australia (Atherton, 1941).

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* Appendix V B, pp. 155–160.

The realisation, at first gradual and finally sudden, of the world-wide distribution of this pest is worthy of comment. Although it had been known in the United States since 1898 and had been reported from the Hawaiian Islands during 1906 and from the West Indies during 1912, a considerable time elapsed before it was recorded elsewhere. Then, in 1934, the sterility or partial sterility of the heads of *dura* in the Anglo-Egyptian Sudan was found to be caused by this midge (Cowland, 1936). It was apparently first found in Queensland in 1928, although it did not attract much attention until 1938–39 (Atherton, 1941). Some years later, Callan (1945) pointed out its almost world-wide distribution. In 1948, specimens arrived from Venezuela and Indonesia. Since then, as many present will know, it was recognised in quick succession in Nyasaland, Uganda, the Aden Protectorate, the Gambia, the Gold Coast, Kenya, Tanganyika and Nigeria. In fact, it is now known from all the larger areas of sorghum production with the exception of the Indian sub-continent. But here two other very similar species of gall midge are responsible for identical damage. *Contarinia caudata* was described in 1920 and the *cholam* or *jola* ear-head midge (*Contarinia andropoginis*) in 1921, both from South India (Felt, 1920 and 1921). *C. caudata* has since been found in Pakistan, while *C. andropoginis* is the sorghum grain midge of Burma.

Some taxonomists consider that *Contarinia caudata* is only another name for *C. sorghicola* and that only one species is involved. But I want it to be realised that the separation of gall-midge species solely on morphological characters, especially in dealing with large series from various countries, is not at all satisfactory. I am of the opinion that it has now been proved that the biological approach to the species problem is essential. Some groups of gall midges contain species that are apparently morphologically identical but can nevertheless be separated quite satisfactorily by the evidence of their host plants. Biological experimentation has also demonstrated that some other species have a much wider host-plant range than was previously known or even suspected. For want of better terms, I have designated (Barnes, 1953) these two types of species, respectively, as " tight " and " loose " or " central " species. It appears likely that " tight " species may arise comparatively quickly by continued isolation on a particular host plant. Such " tight " species would not necessarily at first exhibit any morphological differentiation from the " loose " species from which they originated. In fact, I would go so far as to suggest that physiological adaptations, necessary for life on the sap of a particular host plant, might be expected to arise long before their reflection in the insect's morphology.

Is the sorghum midge a " loose " species breeding on a number of grasses or is it a " tight " species restricted to the sorghums ? Or does the sorghum midge as we know it consist of several species that have arisen independently by convergent evolution in the various countries, or is it one species being transported from country to country with the sorghums ?

A better knowledge of its host plants would help to answer the first of these questions. The alternative host plants of the sorghum midge in the United States are Johnson grass (*Sorghum halepense*) and Sudan grass (*S. sudanense*), and it also breeds on these two grasses in Australia and on *S. halepense* in the Anglo-Egyptian Sudan. In Uganda, it breeds on *Sorghum verticilliflorum* (Geering, 1953). Mr. Geering also recorded it from *Eleusine coracana*, but this was due to an error in identification on my part. The gall midge on *Eleusine coracana* in Uganda is in fact a distinct species. In Nigeria, Mr. Sutherland has made a survey to discover the extent to which the sorghum midge occurs in that country. He has shown that it is widespread.

In addition, it is apparently breeding there on *Sorghum arundinaceum*, several varieties of *S. caudatum*, many varieties of *S. durra* and *S. guineense*, *S. saccharatum* and apparently also *Andropogon gayanus*. In the Gold Coast, Mr. Bowden has reared the sorghum midge on *Sorghum arundinaceum* as well as on *S. guineense*.

The second question—whether the sorghum midge as we know it consists of several species that have arisen independently in the various countries or is one species that is being transported from country to country with the sorghums—can, I think, be answered only by biological experimentation.

As far back as 1935, I obtained Ministry of Agriculture licenses to import living sorghum midge from Texas, and from the Anglo-Egyptian Sudan in order to see if these midges would interbreed. However, I could not succeed in rearing the midges from the two countries synchronously. I am now in possession of further licenses in order to pursue the same general idea and particularly to attempt to discover if *Contarinia caudata* and *C. andropoginis* from India, Pakistan and Burma are the same midge as that which we recognise as the sorghum midge, *C. sorghicola*, from elsewhere.

But the sorghum-midge problem is not so simple as this. Mr. Sutherland in his Nigerian survey reared two other distinct species of gall midge, each of which could easily become pests of grain production—one of these seems to be fairly widespread in Nigeria and occurs there on at least two varieties of *Sorghum guineense* and on *S. arundinaceum*; while the other has so far been reared only on *Andropogon gayanus* at Yandev.

I hope this carries conviction of the seriousness of the sorghum-midge problem. If not, I must point out that Mr. Sutherland in his preliminary breeding experiments to discover the host-plant range of the sorghum midge reared four gall-midge species from *Panicum maximum*. One of these is exceedingly similar to the sorghum midge, the second is also a Bifila but distinct, the third is a Trifila, while the fourth belongs to a different tribe of the Cecidomyidae—the Lasiopterariae. Each of these species is a potential pest of grain production. Mr. Sutherland also found two distinct gall-midge species on *Pennisetum pedicellatum*—one of these is a potential pest, the other is a predatory form. The same story comes from Mr. Bowden in the Gold Coast. Here three distinct species have been reared from *Pennisetum polystachyon*. One of these is exceedingly similar to the sorghum midge, the second is a Trifila, while the third belongs to the Lasiopterariae. In addition, you must not forget the gall midge that Mr. Geering reared on *Eleusine coracana* in Uganda.

If this is not enough to stir up action, I must mention that the rice stem gall midge (*Pachydiplosis oryzae*), a relatively well-known pest of paddy on the Indian sub-continent and in the Far East, has recently appeared at Kayo in the French Sudan and at Masa in the Anglo-Egyptian Sudan. This should give rise to grave concern to those endeavouring to increase the world's rice production. Lastly, as I have pointed out in my memorandum, several other species of gall midges have already been described from the stems of tropical cereals and grasses. The available information concerning the bionomics and economic significance of these species is frighteningly little.

It will be asked what possible control measures exist to combat these pests. There are the cultural measures enumerated by Walter (1941 *a* and *b*), but the best hope of thwarting the sorghum midge and other species that attack the inflorescences seems to me to lie in selecting and breeding resistant varieties on the lines that Mr. Bowden & Mr. Neve (1953) are following in the Gold Coast. But to do this effectively, we must know first how many and what species of gall midge are involved. This will entail a lot of research work.

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The Stem-borer Problem in Tropical Cereal Crops

By J. Bowden

Department of Agriculture, Gold Coast

It has been claimed that the damage inflicted by stem-borers of cereal crops is commensurate in scale with that caused by locusts. This claim is not at present supported by many reliable facts, and, in the face of a great deal of scepticism and propaganda, will require much careful work to substantiate. Nevertheless, it is possible to find statements that do lend support to it. In South Africa, losses of maize due to *Busseola fusca* have been estimated at about £1,000,000 annually. In Kenya, damage by the same pest is considered sufficiently serious to warrant legislative control of maize growing, and even to attempt aerial spraying. In Tanganyika, recent work has shown an increase of 40–50 per cent. in yields of sorghum after control of *Busseola*, and this is presumably an annual toll. From the other side of the continent, we in the Gold Coast obtain an increase of 50 per cent. in maize yields with control of *Busseola* and *Sesamia*. If all this is so, it may be asked why the problem of borers, apart from those of sugar-cane and rice, has been so neglected. There are, I think, two main reasons. Firstly, borer attack is seldom a spectacular affair, and even severe infestations may pass unnoticed when they occur, as they so often do, in scattered native crops. Secondly, most entomologists in tropical territories are overburdened with a multiplicity of investigations, many of them concerned with pests of valuable cash crops in which there is an economic or political incentive to find a means of control. A pest of a subsistence crop for which there is apparently little prospect of early or economic control is hardly likely to receive much attention. There are territories, the Gold Coast is one, in which the maize crop particularly is, for many farmers, a cash crop able to withstand a cash outlay on borer control; but even in territories in which it may be uneconomic to spray or dust, there is a case for attempting control, since it would reduce the time and energy spent in producing a given amount of grain so that more could be used to increase production of a peasant cash crop—possibly cotton in East Africa or groundnuts in Nigeria—the returns from which would offset the cost of borer control.

Two of the main requirements of future work on borers are a reliable taxomonic foundation and a standardised method of assessing infestations and losses; I would at present lay rather greater emphasis on the taxonomic aspect. For instance, the widely distributed African species, *Busseola fusca*, displays most marked variations in habits and habitat throughout its range, most important being its alleged occurrence in *Pennisetum purpureum* in East Africa, whereas attempts to find it in this grass in the Gold Coast and, I believe, also in Nigeria have consistently failed. The possibilities here are that one or other territory has misidentified the borer, or that there are at least two closely allied species that would be identified as *Busseola fusca* on present knowledge. To confirm or disprove the latter would require the critical examination of long series from many localities and many plants. Such a study is urgently needed if the many statements concerning this borer are to be reconciled, but it is one that is not likely to be undertaken for some time to come. Similar examples could be cited from practically every major species or group of species, not to mention the whole question of larval taxonomy. It remains true, however, that unless and until these taxonomic problems are sorted out, borer research will be severely handicapped.

The problem of standardising surveys and damage assessments is, of course, bound up with the proper identification of the borer concerned, or as frequently happens, of two or three species. Most previous work has been limited to a statement of the percentages of plants infested, with little or no estimate of loss and with no figures of the numbers of borers involved. Without such an estimate, infestation counts are relatively valueless, since an infestation of 20 per cent. with one larva per stem is not the same thing as 20 per cent. with five larvae per stem. Duerden in Tanganyika has recently linked the degree and the rate of infestation, but unfortunately did not complete the picture with an estimate of loss. This is a problem to which we have devoted some attention in the Gold Coast, and we have used as a starting point an excellent, but apparently little known, paper by Meyers & Patch some 20 years ago, describing a method for assessing the infestation of maize by the European corn borer (*Pyrausta nubilalis*). This method, based on a systematic sample of 100 plants per acre, has been found to be admirably suited to the requirements of a survey in small and scattered native farms, and is one that native staff can carry out with a minimum of supervision. We have made fairly extensive surveys of maize, sorghum and millet, the results of which fall into a fairly consistent pattern; that maize planted with the major rains is usually free of infestation; that maize planted with the minor rains is severely attacked, irrespective of planting date; and that the first generation of borers does relatively little damage in sorghum and millet, whereas the second and partial third do a great deal. These surveys have also provided a mass of information on the species involved, their distribution and relative importance, but do not provide data on the actual loss of crop.

For this problem, we started from the elementary observation that we were bound to find plants that had no borer attack in any crop with less than 100 per cent. infestation, and that if we took a random sample of these plants and compared their yield with that of a similar sample of infested plants, we ought to get some measure of the effect of borer attack. Also, if we knew the intensity of infestation we could relate it to observed losses. This method has produced some interesting figures. We find for instance that 50 per cent. infestation in maize reduces yield by 45–50 per cent. if there are about three larvae per stem, but by only 15–20 per cent. with one larva per stem, while 20 per cent. infestation with one larva per stem reduces yield by about 5 per cent. Such figures, of course, enable us to assess the overall loss of crop in the various maize-growing areas either individually or on a country-wide basis.

It appears to me that a similar system of survey and damage assessment could be used with little or no difficulty wherever native-grown cereals occur, and the benefit would be great, for only when extensive and reconcilable surveys from many areas are made will we be able to present the borer problem as being of the magnitude that I, for one, believe it to be. Here I would insert a comment on an advantage of the small native plot that seems insufficiently appreciated in connection with surveys, particularly in cereal crops. The very smallness of many of the plots means that the number of plants involved must be small, and it is therefore a relatively simple task to check the sample method by a complete count; this establishes the validity or otherwise of the sample beyond dispute, without recourse to a complicated statistical analysis.

There are, of course, many other aspects of the borer problem to be considered, and in the time I have left I cannot do better than follow the lines of the admirable summary given by Dr. Jepson at the International Congress of Entomology held at Amsterdam in 1951.

The relation of borers to alternate hosts is of considerable importance. The proper approach to this requires that the borers concerned should be considered not merely as something found in a cereal crop but as part and parcel of the fauna associated with the Gramineae of the area. In some places the problem will automatically resolve itself into the relation of the borer to the cereal attacked, as for instance where the cereal is the dominant grass. But in many cases, and this is particularly true of forest areas, the cereals are not the dominant species. The need for studies of alternate hosts should require little or no emphasis, since their status and importance have a profound effect upon the usefulness of such measures as stubble destruction, planting dates and cropping programmes. Moreover, a close study of grasses and their associated borers would, I believe, show that many borers are more selective in their host-plant range than is at present thought, and such a result would also have obvious repercussions on the measures just mentioned.

Another biological problem of prime importance is that connected with parasitism. Some success has already been obtained with parasites against borers in the West Indies and South America, and in some Far Eastern Islands and Mauritius, but little or nothing comparable has been done on the African and Asian continents. So far as Africa is concerned, without a vast amount of detailed work it is difficult to see how much can be achieved. A Scelionid egg parasite of *Sesamia cretica* is apparently common in the Sudan, but is a great rarity in West Africa; again, *Apanteles sesamiae* is an important parasite of *Busseola fusca* in some parts of Africa, but, so far as I know, does not occur in the West. Until the causes of such differences are discovered, it will not be possible to utilise parasites effectively.

The recent achievement of Beck in rearing the European corn borer on an artificial diet is of great importance, opening the way for fundamental studies of borer physiology and nutrition. This is work that could be followed up in Britain. There are many species of grass-boring Lepidoptera in this country closely related to the tropical pest species, and it should not be difficult to establish and maintain laboratory stocks of at least some of them. The physiological approach to host-plant resistance is the only one likely to produce results of value with most borer species, and is an aspect that the field entomologist cannot hope to tackle, but it is one in which he could be aided by his university colleagues.

Of the problems connected with chemical control two are outstanding. The first concerns the formulation of, particularly, a suitable dust, one that has considerable adhesive powers and can be used under a wide variety of field conditions. A great deal of the conflicting evidence on chemical control of borers, especially by the use of DDT, is no doubt due to incorrect identification of the insect, and therefore inadequate or incorrect knowledge of its biology, but there is equally no doubt that the diverse formulations used, with their variable characters and performances, are also partly to blame.

Secondly, we badly require a simple hand dusting machine. There is no need to reiterate the properties required of any piece of equipment issued to unskilled operators. But, nevertheless, something a little more accurate and efficient than the cigarette tin is required.

This has been a very rapid and sketchy outline of the borer problem as I, and I believe some other people, see it. I would conclude by saying that it can be tackled to only one way, not by asking territorial entomologists to divert more of their time in it, but by organising a Commonwealth team to investigate borer biology and control as a coordinated project.

Discussion

The CHAIRMAN said that he was familiar with sorghum-midge attack and that the devastation caused could be remarkable. It was also remarkable that it was often overlooked or attributed to weather conditions. Weather was often blamed for head-sterility in sorghum, but although it might favour the midge, it could not in itself cause the damage for which midge was responsible and which, if the interior of the head was examined, could readily be detected. In a note published in *Nature* (**172** 551) in September 1953, Messrs. Bowden and Neve had drawn attention to one group of varieties of sorghum, found in the north-eastern Gold Coast, that showed resistance to infestation, apparently because the glumes did not open and the midge had difficulty in ovipositing within them. In correspondence with other territories, he had suggested that requests for seed of a typical variety of this group should be sent to Mr. Bowden, who had, however, received only one request before he left the Gold Coast recently.

Dr. G. A. PATEL said that the rice midge, *Pachydiplosis oryzae*, was a serious problem in many parts of the Indian Union. Its bionomics were being studied in Bombay State, in parts of which temperature and humidity were relatively constant for days together. The incidence of infestation was influenced by the distribution of rainfall, though not, perhaps, by the total rainfall. From data obtained in 1950–52, it appeared that the maximum infestation was low when there were sharp peaks in the weekly average rainfall in June and July, but was as high as 25 per cent. when the rainfall was relatively even in June, July and August. It was also observed that infestation was increased if the water level in the rice-field was high, and that the midge lays its eggs on the surface of the water and the larvae enter the stem below it. This last observation suggested the possibility of control in insecticides applied in the way in which they were used against mosquito larvae, either in oil films on the water surface or in pellets thrown into the water. Some consistent differences in the infestation of varieties of rice had been noted, and further work on them was being carried out.

The CHAIRMAN said that some years ago he had had under trial in Burma a variety of rice known as " Faya ", from Nyasaland, that proved very resistant to *Pachydiplosis* midge.

Mr. J. A. WHELLAN said that adults of the borer attacking *Pennisetum purpureum* were reared in Southern Rhodesia early in 1954. Some of them had been sent to the Commonwealth Institute of Entomology, and their identification as *Busseola fusca* was confirmed by Mr. W. H. T. Tams of the British Museum (Natural History). Attempts to induce the borer so reared to infest maize were unsuccessful, so that two races may be involved, but a further effort to clarify the situation would be made in the next growing season. The work in the last one had been seriously hampered by an outbreak of the armyworm, *Laphygma exempta*, which deflected the attention of the small staff available. He therefore supported Mr. Bowden's suggestion that the stem-borer problem should be allotted to a Commonwealth team, whose entire energies would be devoted to it, and not left to local entomologists with limited time to give to it.

Mr. M. E. Solomon said that an underlying problem in the control of pests was to find what factors determined their abundance. If it could be shown that the number of host-plants did not have an important effect on the abundance of the sorghum stem-borers, it might be possible to reduce losses simply by using high-tillering varieties, which was equivalent to growing smaller plants with more of them per acre. The same number of borers would then cause a smaller percentage loss.

Mr. Bowden said that he had been studying *Poeonoma serrata* for 4-5 years in the Gold Coast, not because it was an economic species, but because it was monophagous and occurred all the year round on elephant grass (*Pennisetum purpureum*). It was not affected by the abundance of its food-plant, which was always available for it. Population figures from 1948 and meteorological records from 1950 were available. A preliminary conclusion drawn from their comparison was that the main factor in fluctuations of the population was saturation deficit and consequent desiccation of the first-instar larvae in the leaves of the plant. Shortage of food-plants could not be a limiting factor in the case of *Sesamia botanephaga*, as it was a polyphagous species that attacked many wild grasses as well as maize and sorghum, but the maximum and minimum of oviposition were closely related to the minimum and maximum saturation deficit. The percentages of plants infested by a given number of larvae per acre varied inversely with the number of plants and was much higher in maize than in elephant grass. Thus, Mr. Solomon's point appeared to be of great importance. Attempts in this connection had been made to introduce a rapidly tillering dwarf variety of sorghum, but the native growers objected to it because the large sorghums, with stems 10-14 feet long, were used as building materials.

Mr. C. R. Wallace referred to the suggestion that apparent differences in the food-plant ranges of a given species in two widely separated areas would be explained if an increase in taxonomic knowledge showed that two closely allied species were, in fact, concerned. He put forward the alternative suggestion that radical changes in the feeding habits of a single species might be induced by its transfer to another continent or distant region. The white-fringed beetle, *Graphognathus leucoloma*, was a possible example of this. Of South American origin, it became a major pest of many crops in the southern United States, where close study has revealed a well-defined pattern of preferences. It appeared in New South Wales as a pest of lucerne about 1931 and although it had been an occasional pest of other crops, lucerne appeared to have remained its main host there, although this is not the case in the United States.

He also referred to the view expressed at previous meetings that manual dusting machines suitable for use by unskilled native labour are not in production. His own field experiments in British Guiana led him to believe that the " Root " rotary duster (Model C–3B) was capable of efficient operation under severe conditions and rough handling, provided that corrosive dusts such as BHC were removed from the hopper after use. Two other makes of hand rotary duster proved unsuitable as they lacked efficient provision for lubrication.

Dr. R. H. Le Pelley said that pests of cereals that had become recognised as of major importance in Kenya in recent years included Dynastid beetles of the genus *Heteronychus*; chafer grubs, especially the Melolonthid *Schizonycha* sp.; *Dasus* sp. and other Tenebrionids; *Nematocerus* spp. and other Curculionids; various cutworms, the armyworm *Laphygma*, and the well-known stalk-borers, particularly *Busseola*.

The subject of cereal pests was considered at a recent specialist entomological conference for the whole of East Africa, and further work on them was strongly recommended in view of the vital importance of cereal food crops, the great losses caused by their pests, and the fact that no methods for the control of some of them were known.

Mr. P. T. WALKER said that some of the newer insecticides were highly effective for stalk-borer control. For example, the median lethal deposit of isodrin for first-instar larvae of *Busseola* in contact with it for only 1 minute was of the order of 2 mg. per sq. metre in laboratory tests. There was thus a great possibility of using these materials in control, particularly if the duration of action of the deposits could be prolonged, perhaps by resins. With regard to the alternative hosts of *Busseola*, he said that the insects bred on *Pennisetum purpureum* were merely taken from the usual breeding cages and were not specially identified. Recently, in Tanganyika, *Proceras* sp. had been brought to maturity on *Pennisetum purpureum* from the field. As regards the proposal for formation of a team, he thought that any increase in co-operation would be a real advance in co-ordinating the various aspects of cereal stem-borer control.

Dr. E. S. NARAYANAN said that the chief stem-borers in India were *Schoenobius incertellus* on rice and *Chilo zonellus* on maize and sorghum. *S. incertellus* was a serious pest in the whole of South-East Asia and had been effectively controlled in Japan during recent years by the use of Folidol. This insecticide had also shown promise in India, but had not been recommended for general use, in the absence of data on its toxicity and persistence on the plant. It was feared that cattle might be poisoned by it, because the straw left after harvest is used as fodder, a practice that is not adopted in Japan. *C. zonellus* was a serious pest of maize and sorghum in India, but it had recently been found that two parasites, *Bracon brevicornis* and *Chelonus* sp., attack the larvae there. A technique had been developed for mass-rearing them in the laboratory on an alternative host (*Corcyra cephalonica*) with a view to experiments on the value of releasing them against *Chilo zonellus* in the field.

Dr. W. F. JEPSON said that the stalk-borer problem was one that lent itself to co-ordinated studies, and its importance was emphasised by the fact that it occurred as a major item in no fewer than seven of the summaries prepared for this Conference. The following were salient points that required special attention. In the systematic field, revisions should be made of the Schoenobiines (which include the important rice and sugar-cane borers of the genera *Scirpophaga* and *Schoenobius*), the Asiatic species of *Sesamia*, and the genus *Chilo*. The relation between alternative host-plants and the infestation of cereals should be elucidated with the aid of "blanketing" treatments by insecticides that give complete freedom from insects over the experimental area. The damage caused should also be assessed as a standard practice by the use of blanketing techniques in the way described by Mr. Strickland (pp. 78–83). In view of the variety of experience with various insecticides used for control, laboratory bioassay to establish dose rates for the very young larvae wandering on the foliage was of great importance. An extension of the work on biological control should not be hindered by any inhibition regarding the application of the method to continents. The main parasites of the cereal borers were Diptera in the New World and Hymenoptera in the Old, and exchange of some of the dominant species of each should be considered.

He put forward three suggestions:—

1. An expedition, headed by an entomologist experienced in the special field of stalk-borers, should be despatched to New Guinea to make ecological studies of the occurrence of stem-boring insects and their parasites in cultivated and wild grass associations.

2. A meeting of research workers in the African continent should be held, with a view to co-ordinating research on the ecology and control of stalk-borers, in particular the maize stalk-borer, *Busseola fusca*, and the maize and sorghum borers of the genus *Sesamia*. The development of standard methods of studying and expressing population fluctuations in the field should be the main objective of such a meeting.
3. At least one entomologist should be appointed to deal exclusively with the systematics of stalk-boring insects. He should be based at the British Museum (Natural History), but it should be a part of his duties to visit centres of stalk-borer investigation, in order to link up larval with adult material.

Dr. Jepson concluded by suggesting a resolution that might be considered by a later session of the delegates. It was to the effect that in view of the world-wide importance of insect infestation of tropical cereals, including sorghums, millets, maize and rice, immediate action be taken to set up a research team to study these pests in all their aspects. Its intention was to embrace both the important groups of pests—the gall midges and the stem-borers—that had formed the subject of the discussion.

The CHAIRMAN suggested, and the delegates present at the meeting agreed, that this resolution should be referred to the General Committee (p. 12).

DISCUSSION ON THE DEVELOPMENTS IN WORK ON PESTS OF STORED PRODUCTS

Chairman: Professor J. W. Munro, C.B.E.,
Professor Emeritus, *University of London*

The CHAIRMAN said that research on the insect pests of stored products was increasing, and that the number of entomologists now concerned with it was quite large. He thought that the meeting would conclude that the field of this research was profitable, and Mr. Herford, who was Director of the Pest Infestation Laboratory, would give the opening paper and would outline the way in which it had developed. Mr. Herford, before giving his paper, paid tribute to the part played by the Chairman in obtaining recognition of the importance of research on this subject and in getting it started.

Developments in Work on Pests in Stored Products

By G. V. B. Herford

Department of Scientific and Industrial Research, *Pest Infestation Laboratory*, *Slough*

In the six years that have elapsed since the last Commonwealth Entomological Conference there has been considerable progress in this field. Much of it has resulted from an increasing awareness of the magnitude of problems that were hitherto largely unsuspected or ignored; but there has also been appreciable scientific progress in technique for improved storage and control methods. This progress has been particularly marked in Colonial territories, as may be seen from the following examples.

In Britain, in addition to a Stored Products Research Sub-committee of the Colonial Office, which leads a very active existence, we have at the Pest Infestation

Laboratory a Colonial Liaison Officer with suitable assistance. This Officer, Mr. D. W. Hall, has already made tours in East, Central, South and West Africa, and very recently in the West Indies. Quite apart from their immediate value to the territories visited, these tours have enabled us in Britain to obtain a clearer picture of stored-product problems overseas, and they have produced an embarrassing crop of problems for attention in the Laboratory.

Mention must also be made of the valuable part played by the Infestation Control Division of the Ministry of Agriculture and Fisheries in providing training courses in stored-products entomology for officers from Colonial territories, and by the Imperial College of Science and Technology, which is largely responsible for training those in receipt of Colonial Office Stored Product Research Studentships.

In Nigeria, there is now an efficient research unit comprised of two entolomogists and two chemists, working in close collaboration with a Pest Control Unit, under the Department of Marketing and Exports. In Tanganyika, two fumigating teams are operating, in charge of men specially trained in Britain. In Nyasaland, considerable practical fumigation is being undertaken by a commercial firm on behalf of the Government. This territory has also employed a trained entomologist for the past two years to specialise in problems of disinfestation and storage of foodstuffs. In Kenya, two people are working under Dr. Le Pelley in the same field, and are doing very valuable work. In the Gold Coast, an assistant agricultural entomologist has been appointed, especially for stored products work, and Sierra Leone and the Gambia are each arranging for entomologists to go out from the United Kingdom to work on local problems of rice and groundnuts, respectively.

In the Caribbean area, one of the teaching staff at the Imperial College of Tropical Agriculture in Trinidad is making a special study of research problems in the field of stored products, and proposals are under consideration for expanding this work on the research and advisory side.

Proposals have been made for the formation of a " Pool " of men trained in the field of stored-products entomology, akin to the other pools of entomologists, of plant pathologists and of soil chemists now operating from this country. Such a " stored-products pool " would be able to supply men for relatively short term investigations in different parts of the Colonial territories, and it was felt that this would particularly commend itself to those Colonies in which it might not be found possible to employ a permanent entomologist for stored-products work. However, as a result of a rather lukewarm response from many of the Colonies circularised, the proposal has had to be shelved for the present.

On the more technical side the following examples of progress may be cited; they relate to fumigation, contact insecticides, and storage method.

Very large quantities of foodstuffs are now being fumigated with methyl bromide under special gasproof sheets. In Nigeria last year, some 82,000 tons of groundnuts were treated in this way, for the control of *Trogoderma granarium* and *Tribolium castaneum*. The groundnuts, decorticated and bagged, are typically stored in pyramids, of up to 800 tons, awaiting transport to the coast. Special sheets have been prepared to cover these pyramids in one piece. Similarly, in Tanganyika and Nyasaland, considerable tonnages of bagged maize are being fumigated under sheets, the figure for Nyasaland in 1953 being some 40,000 tons. I understand, too, that this method of disinfestation is also being employed on a large scale in Pakistan.

The advantages of disinfesting bulk grain in silo bins by circulatory fumigation have now become widely recognised, and it is encouraging to see provision made for this type of control in new silos that are being planned or erected in many parts of the Commonwealth.

Of the contact insecticides, two of the most useful are DDT and γ BHC, but their application to foodstuffs is limited by " maximum tolerance figures " of 7 p.p.m.

and 2·5 p.p.m., respectively. This restriction of dosage does in effect mean that both BHC and DDT are relatively useless for admixture with grain against many of the more resistant species. However, these insecticides, in the form of wettable powders, are being used very widely, and in considerable quantities, for treating the insides of stores and the surface of sacks. Much attention is being given, too, to pyrethrum, usually in conjunction with a synergist, both for sack impregnation and for admixture with grain.

While by far the greater part of harvested foods is still handled and stored in sacks, especially in Colonial territories, there is a growing interest, mentioned above, in the advantages of bulk storage in silo bins. There is, of course, no doubt that post-harvest losses resulting from insect attack can be minimised if produce can be swiftly conveyed to efficient silos, for fumigation and subsequent storage.

A concrete silo installation complete with handling equipment is expensive, however, and where it is intended to conserve grain for long periods, *e.g.* for famine reserves, there is a great deal to be said for the use of specially constructed underground pits. Here the emphasis is on the special construction, for the pits must be impervious to water vapour, carbon dioxide and oxygen. When this impermeability is achieved, the depletion of oxygen and accumulation of carbon dioxide together ensure the complete eradication of insect pests, and grain can be safely and cheaply stored in excellent condition for very long periods.

I have attempted to indicate some of the more striking examples of progress in the control of post-harvest infestation, but the time available is too short for me to give even an outline of the steady progress of the research work that is increasing our knowledge of insect biology, grain physiology, and the more efficient use of insecticides and fumigants. Furthermore, all the various examples given above, as instances of practical advances, still present problems that require solution.

Thus, the gas-proof sheets used to cover groundnut pyramids in Nigeria have perished far more rapidly than had been expected, and their replacement with improved types has proved very difficult in the absence of satisfactory expert advice. The distribution of fumigant within the large stacks of produce being treated is still insufficiently known, and there have been indications in at least one territory that *Tribolium* may be surviving on a fairly large scale in fumigated maize.

In Nigeria again, where groundnut pyramids are regularly sprayed to prevent infestation from flying *Tribolium* adults, it has been found that the toxic life of BHC, applied as a wettable powder, is only a fraction of what it is in a temperate climate. The possibility of extending the effective life of this otherwise useful insecticide, or of finding a suitable alternative, are matters of the greatest urgency and importance.

Underground pits have been mentioned as being useful for famine reserve storage. Here again there are many unanswered questions. What, for example, is the highest moisture content at which grain can be stored in this way ? Does it vary from one type of grain to another ? Can paddy be stored in pits ? If a long pit is required, are expansion joints necessary, and will they affect the impermeability of the walls ?

These few " unanswered questions ", and many others far too numerous to mention here, are a reminder that, while we can point with some satisfaction to the progress made during the past few years in this field, we have a great deal to learn, and the savings so far achieved, whether of money or of foodstuff, are small in relation to those that will, I am convinced, be ultimately possible. Although some of the outstanding problems can be tackled in Britain under controlled physical conditions, there are many on which research can be adequately undertaken only in a tropical climate. I refer particularly to work on storage problems. There is, in my opinion, a real need for the provision of good research facilities somewhere in the tropics, preferably in a humid climate, for work in this field, and I would like to enlist the support of the Conference towards the attainment of this end.

Finally, there remains the question of the estimation of post-harvest damage to stored foodstuffs due to insect attack.

I have purposely used the word " damage " as opposed to " losses " in this connection, because there are many ways in which the quality of a foodstuff can be affected quite apart from the actual loss of material. For example, groundnuts that have been infested in storage suffer a considerable increase in free fatty acid content, due, in the main, to the increased surfaces of the insect-riddled nuts exposed to oxidation. In severe cases, the financial loss from this cause can exceed that arising from actual loss of weight.

Statistics showing post-harvest damage to foodstuffs arising from infestation are helpful and often necessary when authorities are being urged to start or expand scientific work in this field. Apart from certain rather generalised global figures, put out, fortunately, by very eminent authorities and widely quoted, we have all too few properly authenticated instances of damage to quality or actual losses of weight, and we would be very glad to receive further information.

Discussion

Mr. G. H. CASWELL pointed out that work on the control of pests of stored products should not be confined to products of value for export but should also be applied to food crops stored for local consumption. Thus, in Nigeria, cacao and groundnuts were adequately looked after, but severe damage to cowpeas, maize and sorghum was ignored. The damage to cowpeas by Bruchids was seldom less than 50 per cent. In southern Nigeria, two crops of maize were harvested in the year, the first in June–July and the second in December, and December–June was the critical storage period. In an experiment against *Calandra oryzae* a dust containing 0·2 per cent. pyrethrins and 2 per cent. piperonyl butoxide was mixed with maize at the rate of 1 : 300. The initial percentage of whole grains in the maize in January was 82; percentages at the end of storage, in June, were 76 in the treated maize and 14 in the controls.

Dr. K. SALMOND said that the percentages of damaged grains in maize stored in bags in Nyasaland were 28, 32, 40, 47, and 49 after storage for 7, 9, 11, 13 and 15 months, respectively, and the losses in weight at a moisture content of 11 per cent. after the same periods were 5, 8, 13, 14 and 15 per cent. Surveys of maize in cribs at the end of the wet season in Nyasaland villages showed that 65 per cent. of the cobs were damaged and that the average damage per cob was 8 per cent. The amount of insect dust and insect material at the end of 15 months' storage were 3 and 0·2 per cent.

Dr. TASKHIR AHMAD said that a recent surplus of food grains in Pakistan had produced the problem of fumigating large quantities of wheat for export. In the absence of fumigating chambers, attempts were made to fumigate the grain in ships' holds, though practically no information on this method of fumigation was available. The cargo was fumigated during the voyage and ventilated at the next port. The effectiveness of the treatment was assessed from the mortality of examples of various pests of stored grain in wire-gauze cages buried at different depths in the wheat. The fumigant was a mixture of ethylene dibromide and carbon tetrachloride applied at rates of 15, 20 and 30 lb. per 1,000 cu. ft. of hold space, and 80–100 per cent. mortality of the test insects was obtained with rates of 20 or 30 lb. Some 1,800,000 tons had been treated in this way.

Mr. D. W. HALL stressed the importance, now becoming increasingly more evident, of being able to assess the losses caused by the pests of stored products. In 1946, a committee of the United Nations Food and Agriculture Organization estimated that the world food loss caused in temperate and tropical countries by insects, fungi and rodents was 10 per cent. No accurate estimate of the losses in tropical territories had been made, but small items of information had been gradually accumulated during the past five years and some examples of them might be of interest. One African territory, in which maize was stored in bags in very poor storage premises and without control measures, estimated the loss of weight over 12 months' storage to be 17 per cent. Estimates in another African territory were that the loss was 3 per cent. in a normal storage year, that this loss was reduced by 50 per cent. (to 1·6 per cent.) by the building of large tight stacks and the dusting of each layer of bags with BHC as the stacks were built, and that the consequent financial saving was £50,000. Large quantities of groundnuts were imported into the United Kingdom from West Africa for the manufacture of margarine. The acidity of the oil of these groundnuts was about 7 per cent. If this could be reduced to 3–4 per cent. by controlling insect infestation of the groundnuts in West Africa an extra 9,000 tons of margarine would be made available. Moreover, insect infestation of groundnuts from one West African territory was estimated to cause a loss of some 1,650 tons of nuts (i.e. about £90,000) or of oil worth some £150,000.

It was extremely important to be able to show the overall losses that were occurring primarily from the point of view of food loss, which could be measured by actual weight loss, the percentage of damaged grains, and the reduction in nutritive value as shown by the increase in acidity, etc.

Infestation problems often involved more than information about the quantity of insecticide or fumigant necessary to kill the pest in a particular commodity. In tropical territories, it sometimes proved impossible to carry out certain control measures because of socio-economic conditions. The control of Bruchids in peas and beans had been solved scientifically and was now an administrative problem. Unfortunately, local practices and politics played an important part in solving storage problems in tropical territories.

Mr. T. A. OXLEY said that stored-products work was relatively simple compared with field research. There were fewer organisms, and the physical conditions were slow to change, easy to measure and capable of fairly simple theoretical analysis. It was therefore much easier to centralise research effectively than it was in the agricultural field. This was perhaps part of the reason why the " young science " of stored-products entomology had been able to make very useful advances in a fairly short time. Mr. Herford's suggestion that a tropical stored-products research laboratory should be established was therefore very useful. Such a laboratory could do work that would be valuable to all tropical parts of the Commonwealth, whereas no single institution could do the same for an agricultural problem. There was real need for work on stored products in a tropical climate to supplement the work in the United Kingdom, because it was quite impossible to simulate tropical conditions properly in a temperate climate.

Dr. E. S. NARAYANAN said that in India 3½ million tons of food grains were damaged annually by insects. Much work had been done on all aspects of this problem, but they were not encouraging the use of DDT and BHC, except for treatment of seed grain, because of the risks believed to be involved, and he would like Mr. Herford to tell him the maximum dosage that could be safely used in grain for human consumption. In this connection, they were developing the use of pyrethrum, which was being grown in the Nilghiri, Kashmir and Assam regions.

Dr. SALMOND, referring to the storage of grain in specially constructed underground pits, said that unlined pits were in use in the Sudan and appeared to be satisfactory. She suggested that a polythene material might be used to line pits. Ruberoid material was unsuitable for covering pits as it was too easily damaged. In Tanganyika, the grain remained in the storage pits only from one season to the next, but long-term storage was required in Central Africa, where famine conditions might be expected to occur once in five years. It was not known if they could store grain in pits so long. A trial pit in Nyasaland had shown itself successful, entomologically, when examined after 18 months, but hair cracks had developed in the cement lining; bitumen was being used to overcome this trouble. The importance of oxygen tension should not be ignored; the carbon-dioxide concentration did not exceed 12 per cent., which is about half of what is obtained in Argentina.

Prof. T. W. **KIRKPATRICK** commented on the proposed team for research on tropical stored-product problems. He said that, although the matter was still under consideration, it had been suggested that a Regional Agricultural Research Organisation for the West Indian area should be set up and that one of its activities should be research on stored products. Trinidad was eminently suitable for research on problems of the damp tropics, there were good library and laboratory facilities available at the Imperial College of Tropical Agriculture, and excellent scientific contacts. If the Conference supported this suggestion, a resolution to that effect might be proposed.

Mr. **HALL** considered that the need for fundamental research in the tropics could not be overestimated, but that it was also essential to take into account the fact that a territory with a storage problem felt that this problem could be solved only by work within its boundaries. Unless the value and local applicability of a new method of storage or disinfestation was demonstrated to those in authority in a territory by a pilot scheme there would be no hope that money would be expended on it there. Progress consequently depended on making available trained staff to tackle the problems that were now known to occur in a number of territories and to which increasing importance was attached because of the existence of a buyer's market.

Many territories wanted problems investigated but were unwilling or unable to commit themselves financially to the full-time employment of a stored-products worker, especially if he was to work on the biology of the pest, as the immediate economic value of such work was not evident. Future development, therefore, depended on the formation of a " pool " of stored-products workers adequate in number to enable specialists to be allotted to territories for short-term periods with a maximum of some 2–3 years. The speaker strongly recommended the conference to consider the need for such a pool, as well as for a unit in a tropical territory to carry out fundamental research.

Dr. D. W. **WILLIAMS** said that it was sometimes forgotten that the remarkable strides made in stored-products work during the last few years had their basis in some fine biological work carried out over many years prior to the institution of the various pest-control organisations. Fundamental work on life-histories, physiology and general ecology should not be sacrificed for more superficially attractive work.

Knowledge of the biology of pests of stored products was used in many control operations carried out in the United Kingdom. It was useless to spray against *Ephestia elutella* for some nine months of the year, because the insects were protected from the spray during that time. Grain infested with *Tribolium castaneum*, *Calandra oryzae* or *Ephestia cautella* need not be treated if it was to be stored in the autumn in stores of such a size that the insulating properties of the grain were not an important factor, because these insects would not survive the normal winter temperatures. It was known too that *Tyroglyphus farinae*, one of the most important of the grain pests in Scotland, would not flourish in grain with a moisture content below 12 per cent. Most of the imported grain came in at 11 per cent., and if an economic method of keeping it below 12 per cent. had been found, 75 per cent. of the grain fumigations carried out in Scotland over the past few years would have been unnecessary. The factors mentioned referred primarily to the United Kingdom, but it was possible that further work on the biology of the pests would assist their control in tropical countries. References had been made to the pit storage of grain, but there appeared to be insufficient information on the levels of carbon dioxide necessary to ensure control. There was, of course, a precedent for this type of work that might give hope to those engaged on it, in that Joseph kept grain for seven years in Egypt without the use of insecticides.

The greatest real progress in the control of stored-products pests would come from the continuation and expansion of work on their life-histories, physiology and general ecology. It was more important to recognise the presence of living insects before fumigation than to count the dead ones afterwards.

Mr. HERFORD referred to some of the points that had been brought up. He realised that cowpeas were heavily infested in Nigeria, as Mr. Caswell had pointed out, and said that a vacancy in the West African Stored Products Research Unit for work on storage pests of local food crops had been authorised. In answer to Dr. Narayanan's question regarding the highest dosages of DDT and BHC that could safely be used for the treatment of grain for human food he said that he would have considered a relatively high dosage permissible if Dr. Narayanan himself had been the one to apply it, but in practice the treatments would be applied by workers who could not be expected to be so accurate. He exemplified this by saying that the BHC tolerance was 2·5 parts γ isomer per million, but the limit for practical use had been fixed in Kenya at 1 p.p.m. because it was realised that those applying the treatments might not be accurate about decimal points, and because they might be applied more than once. He thought the tolerance of 2·5 p.p.m. allowed a big safety margin, especially in the tropics where the residues would not remain so long. In a brief discussion with Dr. Salmond, he ascertained that the work in which storage in unlined pits had been found satisfactory had not been published but was carried out in a dry area; he thought it possible that the factor controlling infestation in such pits was really the dryness of the air, as the initial moisture content of the grain was presumably low. He thought Dr. Salmond was right in regarding lack of oxygen as more important than the concentration of carbon dioxide, a view supported by work done at Slough and in Australia. He strongly supported Dr. Williams' opinion that biological work was of paramount importance. He hoped that the Conference would support the proposal for the establishment of a research unit for the study of pests of stored products in the tropics.

The CHAIRMAN, who had said earlier in the discussion that he would like to support the proposal, although he was not a delegate, then ascertained the wishes of the meeting, as a result of which a resolution was subsequently considered by the General Committee and adopted by the Conference (p. 12).

DISCUSSION ON THE PROBLEMS OF FOREST ENTOMOLOGY

Chairman: Mr. F. S. Collier, C.B.E.,
Forestry Adviser to the Secretary of State for the Colonies

The CHAIRMAN introduced the authors of the two opening papers which, he said, were concerned with two entirely distinct aspects of forest entomology, the first with the problems presented by pests of timber and the second with virus diseases of two defoliating insects and their utilisation in Canada.

Some Problems in Forest-Products Entomology

By R. C. Fisher

Department of Scientific and Industrial Research,
Forest Products Research Laboratory, Princes Risborough

It gives me and, I am sure, all forest entomologists within the British Commonwealth, great satisfaction that their specific branch of applied entomology has reached a stage in its evolution and growth that merits a discussion of some of its problems at this Conference. That distinction is in itself an indication of the increased attention that has been given, particularly since the war, by foresters and timber users to the damage caused to their crops and products through the activities of insects and the realisation that the entomologist has something to contribute towards a solution of the problems they cause.

In introducing this discussion, it is obviously impossible for me to cover the whole subject and I shall therefore restrict my remarks largely to forest-products entomology, timber insects, upon the control of which many of you as agricultural entomologists may sometimes be asked to advise. It is greatly to be regretted that so few forest entomologists from overseas can be present to tell us in person of their work and its progress, but I hope that to-day's discussion may stimulate the interest of entomologists in other fields and lead to greater support for the work of their forestry colleagues who, at least in the Colonies, have usually to blaze a lone trail in tackling their particular problems.

It has always been my opinion that there can be no hard and fast line of demarcation between the work of the entomologist concerned with the pests of growing trees and that of his colleague dealing with insects attacking timber after felling and conversion, or in manufactured goods and buildings—in other words, pests of forest products. The various factors, whatever they may be, that lead to infestation of trees—whether by defoliators, plant lice, bark borers or what have you —may have an important effect on their susceptibility to attack by wood-borers that cause damage to the timber, affecting its value and restricting its uses. In the early days of forest entomology, attention was devoted almost exclusively to the pests of trees and plantations, and you are no doubt familiar with the pioneer work in this field in Canada and with the outstanding developments and progress that have followed, and with work, past and present, in Australia, New Zealand, India and Europe, including the United Kingdom. Forest-products entomology is of much more recent origin, but its growth within the past thirty years or so is noteworthy; investigations on timber insects are now being pursued in most of the British Dominions and active interest is developing, albeit slowly, in the Colonial Territories. A few examples of some of the major investigations now in progress will show how infestation of trees and timber by wood-boring insects is closely linked and cannot be considered as two distinct and different problems.

Ambrosia Beetles (Platypodidae and Scolytidae)

I recall a remark made by Professor Munro in a discussion at the Fourth Imperial Entomological Conference in 1935 concerning the growing economic importance of ambrosia beetles in hardwoods from the tropics. In supporting the need for entomologists qualified to investigate this and other forest insect problems, he deplored the fact that the demand for their services was slight. Since that date the situation has improved; the need is still great, even more so than in the past, and fortunately the demand has increased. This is due largely to the realisation by timber suppliers and users that many so-called " secondary " hardwoods, especially from the tropics, are severely attacked by ambrosia beetles, sometimes in the tree, more frequently in the freshly felled log, resulting in reduction in the quality of the timber owing to the presence of the insect tunnels and associated fungal staining. Tests of insecticide treatments of logs on an empirical basis to prevent attack have been carried out in different parts of the world with varying degrees of success and have yielded conflicting data on the efficacy of the materials used. It is not surprising that such work has failed to find a satisfactory answer that can be translated into commercial practice as an economic possibility, because there is very little information on the biology of the insects responsible, or even on the identity and distribution of the most important species. Trees and logs of the same timber may differ widely in their susceptibility to attack, but the reason for this is not fully understood. The work of F. G. Browne in Malaya and G. H. Thompson in the Gold Coast has opened up new fields of investigation of these insects in the tropics, where the problem is most complex; most valuable work has also been carried out in Canada, Australia and other countries. A review of literature on ambrosia beetles has recently been published in *Forestry Abstracts* (**14** (4), 1953; **15** (1), 1954).

It is gratifying to all interested in this field of applied entomology that a West African Timber Borer Research Unit has recently been set up by the Colonial Office, in co-operation with the Governments of the Gold Coast and Nigeria, to study ambrosia beetles and their control in the West African territories, which are important sources of supply of tropical hardwoods to this country. Whilst the work of this Unit aims at preventing or at least reducing the defects caused by these insects, its initial activities are not concerned with insecticides but with the insects as such, investigating the biology of different species and in particular incidence of attack, in relation to the history and condition of timber, *e.g.* time of felling, presence or absence of bark, moisture content, climatic and other locality factors. The Unit comprises two entomologists in West Africa and a third at Princes Risborough, where the basic relationships between the insects and their associated ambrosia fungi are being investigated in the English oak pinhole borer, *Platypus cylindrus*. In the course of this work, close contact is being maintained with Belgian and French workers who are studying similar problems in tropical Africa.

One of the most important and indeed intriguing problems to be solved with these insects is the cause, chemotropic possibly, of their attraction to freshly felled logs and, much less frequently, trees. As Browne points out, neither the attractant-forming process nor the attractant itself are known, nor are the conditions necessary for the successful establishment of the beetles and the introduction and growth of the ambrosia fungi, which are believed to be the main source of food of the larvae. It has been indicated that fermentation of the sap may be of primary importance, and Browne has suggested that if the attractant could be identified and its production stimulated, specially baited trap logs might be used in place of attempted control by insecticide treatments, which present many practical difficulties during the extraction and handling of timber in tropical forests.

I have spoken at some length on these insects not only because economically they are timber pests causing a type of damage that is of great importance to the timber supplier and user, but also because the results of the intensive work of the Research Unit in West Africa should be of value in other parts of the world, wherever ambrosia beetles are abundant.

Longhorn Beetles (Cerambycidae) in Seasoned Timber

Most of the longhorn beetles attack trees or unseasoned logs, but there are two species worthy of special mention in this discussion.

The first, *Hylotrupes bajulus*, known under a variety of colloquial names of which, in Europe, the house longhorn borer is the most suitable, is typical of the few Cerambycids that are capable of attacking seasoned wood and causes serious damage to structural timbers in buildings. It appears gradually to have extended its range as a timber pest in Europe during the past fifty years or so, and since the late 1930's has been responsible for trouble in buildings in parts of Surrey. It is not a recent introduction, but has long been known to occur in this country; there are instances of past attack, no longer active, in the sapwood of large coniferous timbers in old buildings in the London district. The cause of the present infestation, which is more or less localised, has not been explained, nor is it possible yet to define with any certainty the future status of this insect as a timber pest in the United Kingdom. A study of its distribution and of its rate of development is being carried out by Mr. M. G. White, one of my colleagues at Princes Risborough. So far, the indications are that climatic conditions, especially temperature, may be critical in restricting its activities. The introduction of *Hylotrupes* into South Africa some twenty years ago has resulted in a major timber-insect problem in that country, where conditions are more suitable for its development and the spread of attack. Drastic preventive treatments have had to be enforced in certain areas to arrest its spread.

The second example of a longhorn beetle that must be regarded as an important timber insect is the East African species, *Oemida gahani*, to which Mr. J. C. M. Gardner has directed most deserving attention. This borer is important in Kenya, primarily as a pest of young plantations of cypress (*Cupressus* spp.) and of *Podocarpus* spp., eggs being laid on pruning scars and wound tissue through which the larvae gain entry to the heartwood, and in this way may be introduced to buildings in timber for structural purposes. This has indeed occurred in Kenya, where this insect is also important as being capable of re-infesting structural timbers, causing damage similar to that of the house longhorn beetle. The possibility of the presence of its larvae in *Podocarpus* timber for export raises practical problems that show the need for extending investigations on this insect to determine its host range and the conditions, including temperature and moisture content, most suitable for its development and the spread of attack.

Wood-wasps and Australian Quarantine

Leaving beetles for the moment, I must make mention of *Sirex* wood-wasps, forest insects that are very much in the news in forestry and timber circles in Australia. Time does not permit of a full account of the trouble that is being caused by these well-known insects, to which attention has been directed in the past largely in connection with the introduction of their parasites for biological control in New Zealand. Suffice it to say that they have not been recorded as breeding in Australia, but in view of the introduction and establishment of *Sirex noctilio* in the 1920's in New Zealand, where this species is reported by some authorities to be a serious pest of exotic coniferous plantations, a recent Australian Commission of Enquiry considered what action should be taken to prevent the entry of the insect into Australia following its discovery in imported softwoods, prefabricated buildings and packing cases on arrival in Australian ports in 1951-54. The result has been intensification of quarantine measures, which include treatment at exporters' expense of all timber or goods in which the insect is found, by heat sterilisation or fumigation. As *Sirex* is unimportant as a forest or timber pest in Europe and other softwood-supplying countries, it is not surprising that timber merchants, packing case manufacturers and others are having difficulty in meeting the Australian specification for *Sirex*-free timber, especially as wood of low quality, showing a variety of wormholes, is commonly used for packing cases for goods for export. The situation is complex and its solution presents the applied entomologist with unique problems in advance. There is need for further information on the status of the insect as a primary pest of coniferous plantations in New Zealand and elsewhere before the risks incurred by its introduction to Australia can be reviewed and re-assessed. In the meantime, the action taken by forestry interests in that country can readily be understood even if its repercussions may not have been fully foreseen. The significance of the fungus with which *Sirex* is associated requires further study in relation to the death of infested trees.

Bostrychidae, Lyctidae and Anobiidae

The ambrosia beetles, longhorn beetles and wood-wasps occur in the green, unseasoned wood of trees or freshly felled logs and have at least some interest to the forest entomologist, in the narrow sense of the title, but his forest-products colleague is more often concerned with species attacking seasoned wood or manufactured goods. Termites being outside the scope of this discussion, the insects chiefly involved are adults and larvae of beetles of the families Bostrychidae, Lyctidae, Anobiidae and others, differing in importance according to country and climate—temperate, subtropical or tropical. As it is obviously impracticable at the time at my disposal to deal with each of these families separately, I propose only to mention a few of the more important problems in which they are concerned and to indicate the lines along which research and methods of control are being developed.

At Princes Risborough, we have taken the view that little progress in the development of improved methods of dealing with timber insects can be made without as complete a knowledge as possible of their general biology and of the conditions in timber that are required for the optimum rate of development of different species. This has meant that we have not attempted to develop tests on insecticides and preservatives using insects of which the nutritional requirements in timber are unknown. This policy has no doubt been criticised by those primarily interested in the use and development of insecticides and preservatives, but to the applied entomologist, who is equally concerned with the eradication of attack and the prevention or reduction of losses through infestation by wood-boring insects, it is the only sound basis for work of lasting value and has indeed been amply justified by its results. For instance, the work undertaken at Princes Risborough by my former colleague, Dr. E. A. Parkin, and others on the food-relations of *Lyctus* powder-post beetles has laid the foundation for the control of these and related insects in many parts of the world. A recent enquiry will illustrate this. A year or so ago we were invited by a Colonial Forest Department to comment upon an experiment designed to compare the suspectibility of a number of tropical timbers to attack by *Minthea rugicollis*, a common species of powder-post beetle. The significance of differences in starch content in timber as affected by the origin, history and methods of handling wood had not been taken into consideration in selecting test samples for this work. Without attention to such a vital part of the experiment, its results could not give a true indication of the degree of susceptibility of individual species to this type of insect attack, which is governed by a number of factors, of which starch content of timber is the most important. A related problem that is at present being investigated at Princes Risborough is the comparative susceptibility to *Lyctus* attack of timber that has been seasoned naturally and timber that has been kiln-dried, in relation to the changes that may take place in the cell contents of the wood during each process. These are two examples of the need for accurate botanical and chemical data before the more strictly entomological aspects of the problem of assessing the value of treatments against infestation of timber or plywood by powder-post beetles can accurately be investigated.

In most temperate countries, several species of Anobiidae (furniture beetles) are well-known timber pests, causing damage to structural timbers in buildings as well as in furniture. The ravages of the death-watch beetle, *Xestobium rufovillosum*, in ancient buildings are only too well known in the United Kingdom and are one of the principal causes of extensive repairs, to meet the cost of which the Historic Churches Preservation Trust was recently founded. Intensive studies of the biology of this insect, involving the co-operation of entomologist, mycologist and wood chemist, have provided information on the significance of fungal decay in relation to the susceptibility of timber to attack and its suitability for the nutrition and boring of the larvae. With proper application of such knowledge, there is no reason why the death-watch beetle should ever cause trouble in the future in new buildings. The immediate and more difficult problem with this insect is how to eradicate existing infestation in the massive timbers of an ancient church, or an H.M.S. *Victory*, where application of insecticides is difficult and penetration often inadequate. Under rare circumstances fumigation is a possible alternative, but few reliable data are yet available on the dosages lethal to this and other wood-boring insects, whilst little is known of the penetration and retention of toxic gases in timber.

The common furniture beetle, *Anobium punctatum*, is widespread throughout the United Kingdom and causes much trouble, if not actual structural damage, to woodwork and furniture. As is often the case with a well-known pest—and this insect occurs in most temperate parts of the world—little definite is known of the conditions that invite attack; entomologists can seldom agree even on the normal length of its life-cycle. Extensive work on its control has been carried out in New Zealand, where it is even more troublesome than in the United Kingdom. During the past few years, my colleague, Mr. J. D. Bletchly, has made a detailed study of its biology, paying particular attention to egg-laying and the nutritional requirements of the larvae. Although it has been recorded from many timbers, susceptibility to attack varies greatly within a single species and the reason for this, which may be of considerable practical importance, has yet to be found. The insect is less tolerant of high and low temperatures than the house longhorn beetle, and the moisture content of timber appears to have an important effect on the rate of larval growth.

Conclusions

You will have gathered from these few examples that at Princes Risborough we have concentrated on biological studies of wood-boring insects. This is not to say that no attention has been given to experimental work with insecticides and wood preservatives—far from it, since such work has been carried out and is being extended as biological knowledge increases—but the stage has not yet been reached when, in our view, it is possible to draw up a standard type of test for the evaluation of insecticides comparable to the wood-block or agar test used throughout the world by timber mycologists for assessing the value of fungicides. There is certainly a need for an insecticide test that would yield accurate results capable of repetition wherever specific wood-boring insects are concerned. Attempt to devise such a test have been made in some countries, but are not universally applicable.

In the general field of wood preservation, there has been in the past a tendency in most parts of the world for wood-preserving experts, usually engineers by training, to underestimate or even to disregard the contribution that can be made by the biologist, whether he be entomologist or mycologist, and is essential in the solution of their problems –a rather surprising attitude, since the very need for preservation is in most instances due to the activities of insects or fungi. Nowadays, there are welcome signs of closer co-operation between engineer and biologist in seeking solutions to mutual problems. I do suggest, however, that it is the biologist's responsibility to present his knowledge in a form readily understandable by the engineer, who can contribute much towards the development of techniques most suitable for the application of his recommendations. There is indeed a wide field to be more fully explored in the treatment of timber in bulk or of large dimensions *in situ* in buildings.

I do not propose to comment either on the materials or on the methods at present used for the treatment of timber in different situations, but shall leave such matters to be raised in the discussion. One problem, however, should be stressed as of topical importance in the United Kingdom. Our building programme necessitates the increasing use for structural purposes of timber of far smaller dimensions that in the past, often of poorer quality and certainly with a higher proportion of sapwood —and this applies to hardwoods as well as softwoods. Our home-grown softwood plantations, the entomological troubles of which are under the care of the Forestry Commission's entomologists at Alice Holt, are now yielding thinnings of immature timber with much sapwood. The use of such wood for buildings without adequate preservative treatment, combining the conditions to which I have just referred, favours an increase in infestation by wood-boring insects that could become infinitely more important than hitherto from the point of view of the stability of a structure. Such conditions have played no small part in the increase of damage by timber insects in other countries, but here we have been forewarned and, with the greater entomological knowledge and improved preservative treatments and techniques now available, we should be forearmed.

Finally, may I be permitted a word on the teaching of entomology to specialists in training in other fields ? At Princes Risborough we have the opportunity, during brief courses at the Laboratory, of meeting final-year students from the four university schools of forestry in this country. Their interest in entomology is usually negligible; it is regarded solely as an academic subject that has to be endured in the course of their forestry training but has no practical bearing on their future work as forest officers. This belief could, I am certain, be quickly dispelled by entomologists responsible for short courses to such officers, by bringing out the practical value of the subject, not over-stressing taxonomic details and descriptions of life-cycles of insects of little interest to the forester. Such an approach to forest entomology would do much to stimulate the interest of the student and should later promote his active co-operation in field observation and experiment. It is noteworthy that, within the Commonwealth, forest entomology has often progressed through the efforts and enthusiasm, not of entomologists trained as such, but of forest officers who have been interested in insects and have realised their significance in relation to sound forestry practice.

There are many subjects and problems that there has been no time to mention. Their importance must vary in different countries and under different conditions, but one that is of universal interest and upon which little is known concerns the rôle of parasites and predators in the regulation of populations of wood-boring insects. This subject is well worthy of research, certainly as a fascinating entomological problem if not of immediate value in the control of timber pests.

The Use of Virus Diseases against Sawflies

By F. T. Bird
Division of Forest Biology, Department of Agriculture, Canada

Viruses have been used in the biological control of two introduced insects in Canada, the European spruce sawfly (*Gilpinia hercyniae*), and the European pine sawfly (*Neodiprion sertifer*). Dr. Prebble has included the results of these studies in the general review of forest entomology* that he prepared for this Conference.

The diseases affecting the spruce and pine sawflies are polyhedral diseases. The viruses multiply and polyhedra are formed in the nuclei of the digestive cells of the mid-gut epithelia. Infected cells are found in the guts of larvae of both sawflies about 36 hours after they are fed virus, and death occurs in five or six days at 72° F.

The successes obtained in the use of the viruses in biological control can be attributed to their extreme virulence for the Canadian populations of these insects. This virulence has been maintained. Populations of the spruce sawfly that survived the first virus epizootic (1937–43), and subsequent epizootics, appear as susceptible as the original populations.

The mortality from virus, in infestations of the sawflies in which it has been established, is dependent on population density and is related to the habits of the particular sawfly species. Secondary factors, such as overcrowding and lack of food, are important only as they affect the feeding habits of the insects. Differences in humidity appear to have no effect on the susceptibility of the larvae to infection. In general, larvae reared at high temperatures die more rapidly from virus disease than those reared at low temperatures. Since development of the larvae is similarly affected, they die at about the same stage of development. In the spruce sawfly, very high temperatures (85° F., and above) retard larval development and inhibit virus multiplication. Larvae fed virus and reared continually at 85° F., do not die from the disease, but they die rapidly when transferred to 72° F., or when reared at 85 and 72° F., alternating between the two at intervals of 12 and 24 hours.

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* See Appendix VI, pp. 206–224.

The chief method by which the viruses are transmitted from one year to another is *via* eggs of infected adults. Very little virus, if any, remains on the foliage over winter. Tests have shown that cadavers and infectious material are removed from the foliage by rain and snow during the autumn, winter, and spring.

Many larvae become infected with virus late in larval life and survive because the infected cells are sloughed off, as are the uninfected cells, at the time of the formation of the pre-pupal mid-gut, which is immune to infection. Laboratory studies have shown that large percentages of the eggs of adults developing from these larvae are also infected with the virus. No multiplication of the virus has been observed within the developing embryo, but larvae hatching from infected eggs die in the third and fourth instars.

The adult of the European pine sawfly lays its eggs in clusters, and the larvae feed in colonies. The eggs are laid in the autumn and hatch in the following spring. It is possible to determine the percentage of egg clusters of a population infected by virus by rearing them aseptically in the laboratory during the winter. In the following spring, the occurrence and spread of disease in the same populations can be studied. In one such study, it was determined from laboratory rearings that about 15 per cent. of the egg clusters were infected with virus. In the field, a virus epizootic started from the infection of a similar percentage of colonies of young larvae.

The mortality from virus on a tree depends on the position of the colonies infected via the egg and on the number of colonies. The virus spreads more rapidly down the tree, and a diseased colony at the top of the tree causes greater mortality than one at the bottom. By selecting sawfly-infested trees of uniform size (about 12 ft. high), it was found that little mortality occurs on trees that have five colonies or less and that mortality increased with the number of colonies. One tree had 40 colonies (about 2,400 larvae). All except five male larvae (the males of *Neodiprion sertifer* have one instar less than the females and complete their development several days earlier) were destroyed by the disease, which had been introduced into the plantation two years previously.

Depending on the concentrations of virus used and the coverage obtained, varying proportions of the pine-sawfly populations in different plantations were destroyed. In general, it was found that the control of the insect by virus during the years following its dissemination was greater in plantations that received small amounts of virus than in plantations in which very high percentages of the larvae were destroyed. In the former case, many larvae became infected late in larval life, survived, and transmitted the virus, via the egg, to the next generation. In the latter case, the trees were reinfested chiefly by insects that were in diapause at the first time of spraying, and therefore had not been exposed to the virus, or were infested by immigrants.

The adult of the European spruce sawfly lays its eggs singly, and the larvae feed singly. It is not possible to study the spread of the virus from the progeny of one adult. It has been found, however, that epizootics start each year from the infection of a very small percentage of the larval populations, and the percentages of larvae infected with disease increase rapidly during the growing season.

The virus affecting this sawfly appears to be much more effective at low population densities than the one affecting the pine sawfly. This is believed to be due chiefly to the differences in oviposition and larval feeding. An infected adult of the spruce sawfly deposits its eggs throughout the forest, thereby establishing many foci of infection. The infected adults of the pine sawfly establishes only one focus of infection, since it lays its eggs in one cluster. This is comparable to the inefficiency of some parasitic insects that deposit their eggs in one host.

During the growing season, there are many methods of virus transmission. Healthy larvae come in contact with and feed on the body fluids of virus-killed larvae. Rains and parasitic, predacious and scavenging insects aid in the dissemination of virus. Birds also may disseminate virus. The stomach contents of the cat bird and cedar waxwing were found to contain large amounts of the pine sawfly virus, which was highly infectious even after storage for several months. It is very probable that the virus is transmitted from the droppings of these birds.

Discussion

Mr. G. H. Thompson, referring to the question of infestation by ambrosia beetles, said that logs of hard wood were often rejected in the country of origin unnecessarily, because the pinholes did not penetrate to the heartwood. Thus, West African mahogany that had been lying by railside in the Gold Coast for two years was unsaleable, because the surface was riddled with holes, until examination by a forest officer showed that the holes were confined to the sapwood, after which suites of furniture were made from it. The problem was, however, often acute in the case of the softer hardwoods. In connection with silviculture, he pointed out that many defoliating insects, such as the pine Noctuid, the gipsy moth and the nun moth, often became very abundant and injurious on the continent of Europe, but did not do so in the United Kingdom. The factors responsible for this difference might be associated with climate or availability of food in a suitable condition, but they were not known. Ecological studies of the forest fauna would provide information, and the need for such studies was now becoming urgent in the tropics where most colonies were entering the stage of forest management. The forests now consisted of very large numbers of species of trees in intimate mixture, but problems would arise when the proportion of valuable trees was increased. Evidence of this was the damage sustained in plantations in the Gold Coast, where only a few species of trees were grown together and mahogany and cedars were often seriously attacked by shoot-borers. *Chlorophora* was very heavily damaged by *Phytolyma lata* when grown in nurseries. Control of pests by silvicultural methods was desirable, and this demanded entomological work, which should be started early in the life of a Forestry Department, and should not wait until a problem arose.

Dr. K. R. S. Morris said that, during 1932–37, he had been collecting parasites of the spruce sawfly in Europe, its natural home, with a view to their introduction into Canada. The sawfly was rare as compared with those that attack pine, but occurred in small numbers all over the continent, wherever spruce was grown. An investigation showed that this was due to the fact that it lived in fairly well adjusted balance with natural controlling factors. The first requirement for the successful development of a generation was a period of some 3–7 days of sunny weather in spring for mating and oviposition flights of the newly emerged adults. The eggs and very young larvae could, however, survive only in spruce needles of a soft luxuriant nature: hard tough needles were fatal. Thus, the somewhat rare combination of a sunny spell for oviposition and sufficient rainfall to produce a luxuriant growth of needles was required for larvae to develop in numbers. These and the pupae were then attacked by several species of parasites. The sum total of these controlling influences allowed only sufficient adults to emerge to maintain a low population showing slight fluctuations from year to year.

It was only in 1936 that conditions permitted large numbers of larvae to complete their development. Their numbers in many parts of Bohemia had been sufficient to cause defoliation, and it was easy to collect them in quantity. At this point, however, a polyhedral disease appeared in many places, and it destroyed most of the larvae of the second generation in a few weeks. Polyhedral disease was of more frequent occurrence in the pine sawflies, and was observed to cause complete elimination of full-grown larvae in minor outbreaks on several occasions. It appeared that natural control of sawfly larvae by polyhedral disease occurred in Europe when their numbers became sufficient to facilitate its rapid spread.

Mr. I. F. B. Common, referring to what Dr. Fisher had said about the risk of the establishment of *Sirex* in Australia, said that the latest information supplied to him was that *Sirex noctilio* had, in fact, become established in a small pine plantation near Hobart, in Tasmania. The work described by Dr. Bird had been followed with great interest in Australia, and attention was being directed to the possibility of using polyhedral diseases for the control of various pests. A first record of a polyhedral disease in an insect in Australia had recently been made. Would Dr. Bird say what was the present status of sawflies as forest pests in Canada ?

Dr. Bird replied that the spruce sawfly was no longer a pest. A virus that attacked the pine sawfly was being used against the latter in place of insecticides and had been successfully applied commercially, but because of this sawfly's habit of laying its eggs in a cluster the control obtained was not so effective as that of the spruce sawfly. Parasitism of the pine sawfly by indigenous insects was only moderate, and it was proposed to introduce from Europe the parasites that evidently gave very good control there.

Mr. A. B. Baird said that Dr. Bird had demonstrated a new weapon in biological control and given added reason for optimism regarding its prospects. He had shown that virus diseases could be used both in an emergency and also, along with parasites, for permanent control.

Dr. Fisher, commenting on what Mr. Thompson had said regarding the rejection of timber attacked by pinhole borers, said that it was not known which species penetrated into the heartwood. There was a prejudice against timber showing wormhole of any type, and no distinction was made between those that were harmless and those that contained insects that would continue to damage the wood. Turning to the problem of *Sirex* in Australia, he said he had seen the record of its establishment in Tasmania to which Mr. Common referred and wondered why the trouble it was causing was so recent, as much of the timber imported into Australia as well as New Zealand must have been infested by it in the past. It might be that it was more abundant in softwood timber now being imported from Central Europe, much of which was of low quality.

Prof. T. W. Kirkpatrick said that he had always understood that pinholes enhance the value of timber for pseudo-antique furniture.

Dr. Fisher replied that this was so in the past, but people were now much more alive to what *Lyctus* and furniture beetles could do. He agreed with what had been said at the previous meeting on the assessment of losses by pests of stored products; timber was also a stored product and it was impossible to assess accurately the losses caused by wood-boring insects. The greatest loss to a firm was in good-will. Only last week, a manufacturer who was troubled by *Lyctus* in imported softwood had said to him that infestation discovered before manufacture might cost pence, and if it were discovered during manufacture it might cost shillings, but that replacement if the damage was discovered after the article was in use would cost pounds.

DISCUSSION ON THE DEVELOPMENTS IN TERMITE RESEARCH

Chairman: Professor T. W. Kirkpatrick,
Imperial College of Tropical Agriculture, Trinidad

The CHAIRMAN said that there was no need to introduce Mr. Harris to the Conference. He had been working on termites for a long period, at least 25 years. He was now the officer-in-charge of the Termite Research Unit, the formation of which by the Colonial Office was the direct outcome of a resolution passed at the last Commonwealth Entomological Conference. He called on Mr. Harris to read the opening paper.

Developments in Termite Research

By W. V. Harris
Colonial Termite Research Unit

In 1949, a scheme for termite research in the colonies was prepared by the Committee for Colonial Agricultural, Animal Health and Forestry Research. It was approved by the Secretary of State for the Colonies, and the necessary financial provisions were made under the Colonial Development and Welfare Act. In this way was brought into effect resolution 16 of the Fifth Commonwealth Entomological Conference, and a Termite Research Unit began operations in East Africa at the end of 1949.

The resolution of the Fifth Conference was to the effect that entomologists " be appointed to study termites in the field with particular reference to their biology and their relationship to agriculture and forestry, and to study their taxonomy at an appropriate museum ". It is suggested that the close relationship which we are privileged to enjoy with the Commonwealth Institute of Entomology, the British Museum (Natural History) and the East African Agricultural and Forestry Research Organisation is indicative of our intention to carry this out in practice. We appreciate greatly the assistance that we receive from the directors and staffs of these organisations.

At this moment, the disposition of the four entomologists who form the Unit is as follows:—

> An officer in charge, attached to the Commonwealth Institute of Entomology and accommodated at the Natural History Museum as an Honorary Associate in the Department of Entomology.
>
> One Scientific Officer assisting at the Museum and recently returned from East Africa.
>
> Two Scientific Officers attached to the East African Agricultural and Forestry Research Organisation in Kenya.

At the conclusion of the current period of the scheme under which the Unit functions, each scientific officer will have had a minimum of one year's training in taxonomy at the Museum, and two years' field work in East Africa.

Our main objective at present is to build up the collection at the Natural History Museum so that taxonomic problems can be studied and identifications made for other workers. Taxonomy tends to be regarded as a handmaid of the other branches of biology, receiving the treatment usual to handmaids, but entomologists in the field do appreciate that a serious obstacle to their work is failure to obtain accurate identification of the insects on which they are working. Of course one trouble is that termites lack the spectacular appeal to the eye that attracts the museum specialist to many orders. They look dull and dreadfully uniform when they are dead and in pickle, and the absence of such anatomical characters as external genitalia does not add to their attraction.

The initial location of the Unit in East Africa has given us the opportunity to collect over a wide area, extending from Aden down to the southern end of Nyasaland. As the identification of our specimens progresses, so the field notes that accompany them are being assembled to give a picture of the ecology of each species. In order to have a check on this general picture, since it is not always possible to avoid jumping to conclusions during the course of a collecting trip covering several hundred miles, a detailed study of the ecology of the termites of a small area in north-eastern Tanganyika was made by one of the Unit, Miss Kemp, during the two years in which she was stationed at Amani. This work is shortly to be published. A general account of the common termites of eastern Africa is now being prepared, based on the results of our collecting.

One result of all this work has been to increase greatly the number of species of termites recorded from East Africa. The number of species that occur varies greatly with the particular locality. For example, Dr. Emerson found over 50 different species during a two weeks' stay at a camp in the Ituri Forest, in the Belgian Congo. Tropical rain forest is just what one would imagine as ideal termite country. To most people, it comes as a surprise that there are any termites at all in deserts. The Aden Protectorate as a whole is now credited with 12 species, of which some are proving to be pests, and two at least, *Anacanthotermes ochraceus* and *Microcerotermes diversus*, have been found to accompany perennial vegetation to its extreme limits along the borders of the Empty Quarter. Professor Grassé suggests that termites are probably the commonest animals in the Sahara, and play a correspondingly important part in the rather simplified ecology there. In the deserts of Russian Turkestan, it has been found that the low mounds built by certain harvester termites have an accumulation of nitrates that is of definite value as a crop fertiliser when these areas are brought under cultivation in irrigation schemes.

Taxonomic work soon points to interesting problems of geographical distribution. On the whole, termites in tropical Africa tend to follow the major vegetation zones, but in a number of genera there is a striking variation in degree of correlation. For example, in the genus *Odontotermes*, the species *badius* appears to be happy anywhere between the southern border of the Sahara and Johannesburg, from sea-level up to 8,000 feet (at least in the equatorial mountains), while closely related species are limited in their distribution to quite small mountain ranges. All the termites of Zanzibar are common to the adjacent mainland, and it seems that an island must be really old in the geological sense to have its own peculiar forms. Socotra, which is 160 miles from the extreme north-eastern tip of Africa, has two species of termites, neither of which is found on the adjacent coasts of Africa or Arabia. A common termite of the East African coastal woodlands, which builds nests the size of a football on the trunks and lower branches of trees and of which we have been aware for many years, has now proved on close examination to belong to a genus, *Grallatotermes*, of which the other five species are distributed between southern India, the East Indies and the Phillipines.

And this leads us to the important practical question of the recognition of introduced termites. There appears to be in progress a steady dispersal of the more injurious dry-wood termites around the tropics. These dry-wood termites, *Kalotermes* and related genera, are easily carried around because of the smallness of the individual colonies and their habit of living in woodwork, such as furniture, isolated from the ground and quite self-contained in a very small volume of wood, if necessary. It is imperative that these immigrants should be recognised and assailed before they have got a foothold if control measures are to be worth the attempt. The West Indian dry-wood termite is perhaps the best known of these travellers, but it is not the only one. The spread of certain subterranean termites belonging to the family Rhinotermitidae is less easy to explain. They occupy a half-way position between the dry-wood termites, which they resemble in digesting wood by means of intestinal protozoa, and the subterranean termites, which nest in the soil, go in search of food over long distances, and maintain a more elaborate social system in the colony. These Rhinotermitidae appear to be able to adapt themselves, at least temporarily, to habits of life more like those of the dry-wood termites, and have been found in the timbers of small vessels such as lighters, and in wooden tubs containing growing plants. *Coptotermes formosanus* is one such termite; it is spreading from south-east Asia, and is now established in Hawaii on the one hand, and Ceylon and South Africa on the other. The related genera *Reticulitermes* and *Heterotermes* have shown the most success among termites in adjusting themselves to the cold winters of the higher latitudes. *Reticulitermes flavipes*, native to the eastern sea-board of the United States, is to be found in Europe at La Rochelle and Rochefort, and more recently as far north as Hamburg.

If the morphology of termites is at fault in providing too little material for the taxonomist, the diversity of their biology is not at all restricted, except perhaps that they are uniformly social in habits—there are no solitary termites. There is a great temptation to eke out morphological characters with ethological ones, which would be calamitous for the museum taxonomist. The biology of a termite, as of any other insect, needs to be studied if reasonable attempts are to be made to control it. But apart from such practical considerations, termite biology is attractive because of the social organisation involved. Populations running into millions demand a high degree of organisation. Emerson has estimated the population of a colony of the South American *Nasutitermes surinamensis* at three millions, while Holdaway and his colleagues in Australia recorded between one and two millions for *Nasutitermes exitiosus*. In tropical Africa, a single queen of one of the species of *Macrotermes* that build the very large mounds will lay eggs at the rate of one every two seconds, which is 43,000 a day. If the workers and soldiers in the colony lived only a month, this rate would maintain a stable population of 1¼ millions—but we know that they live much longer than this, and also pairs of queens or even three in one cell are by no means uncommon.

The two termites native to southern Europe, *Kalotermes flavicollis* and *Reticulitermes lucifugus*, have proved to be good laboratory animals and are used on the Continent for testing chemical termite-proofing compounds. This has led to much interesting information being obtained on their biology, especially on individual development and the mechanism of caste determination. We have met with little success so far in our efforts to maintain subterranean termites in laboratory cultures in East Africa, but we have not given up hope. We are particularly interested in the feeding habits and digestive processes of both fungus-growing species and those that appear to subsist on humus.

Termite mounds are a common feature of the landscape in many tropical countries, and, even though it is no longer believed with Sir John Mandeville and the other early writers that they contain quantities of gold, dug up and guarded by ants the size of a large dog, they are not to be disregarded by agriculturist or even civil engineer. The mass of *Macrotermes* mounds in tropical Africa is itself a serious obstacle to mechanised farming. When the Tanganyika groundnut scheme came to clear an area of some 16,000 acres in the Western Province, an average mound population of one to every 1½ acres was found, and the cost of levelling these mounds to allow the machines to plough, harrow and generally perform mechanically the various operations was just what it had cost already to clear the bush—in short it doubled the estimated cost.

Another and more important point is what will be the effect on soil fertility of spreading the soil which makes up the mound. It has long been known that the vegetation on large termite mounds differs from that of the surrounding ground. Crops such as sisal and maize often show up greener and taller on old termite mounds, and peasants from Angola to Siam may prefer to cultivate the tops of mounds rather than the flat ground about them for their crops. When Milne, in Tanganyika, announced that there existed large mounds with a high concentration of calcium carbonate—and since 1937 this has become a generalisation regarding termite mounds in East Africa in some works on soil chemistry—the answer seemed to have been provided for these vegetation differences, and also to the shortage of lime on much tropical agricultural land. There are, in fact, areas in which nodular calcium carbonate is present in sufficient quantity to be used as road metal, and for lime burning. The possible origin of such lime also provides a topic for much interesting speculation. But careful examination of mounds in a number of different localities soon demonstrated that those that showed evidence of lime accumulation were localised in their distribution and in a decided minority. Meanwhile, Pendleton had reported lime in termite mounds in Siam, and the idea appeared to be spreading that mounds were an untapped source of much needed soil fertility. Yet those who had any experience in East Africa of the effects of levelling termite mounds to prepare experimental plots or ground for lawns were well aware of the lower fertility that resulted locally. Dr. Hesse of the East African Agricultural and Forestry Research Organisation has recently concluded a chemical study of the soils of *Macrotermes* mounds in East Africa. He found that all termite mounds tended to have more exchangeable bases than their surrounding soils, regardless of their age, size or location, but that in all other respects they are identical with the nearby subsoil, except in the case of calcareous mounds. As regards these calcareous mounds, he found them only in or near ground with impeded drainage, usually seasonally waterlogged, and uninhabited by the particular termite that could have been expected to have built them. Termite mounds would thus appear to be more fertile than the surrounding soil only where this soil is less fertile than the subsoil, while the presence of lime must be demonstrated for each individual mound before this can be used for the improvement of soil acidity.

Finally, there is the question of termite damage to growing crops. Quite a number of people are so firmly wedded to the dictum that termites will not attack a healthy plant, that they will go to any length to demonstrate a predisposing cause that would lead to the ultimate death of the plant in the complete absence of all termites. Perhaps this attitude arises from the generally unspectacular nature of termite damage to crops, as compared with outbreaks of cutworms, grasshoppers, Aphids and the like, which build up in striking manner.

Mastotermes darwiniensis, in Northern Australia, is not just the most primitive termite now living, but is a pest of many garden plants, fruit trees, sugar-cane and woodwork about the farm. For variety it can, on occasion, penetrate the lead sheathing of underground telephone cables and, by letting in moisture, cause a short circuit.

Dry-wood termites are on the whole interested only in the dead dry branches of trees and to a lesser extent the seasoned timbers of houses. But the genus *Neotermes* has several species that have turned to feeding on healthy living trees and so become pests; examples are *Neotermes tectonae* on teak in Java, *N. gestroi* on cacao in West Africa and *N. militaris* on tea in Ceylon.

A few damp-wood termites have left the rotting limbs and trunks for living tissues, so that we get *Coptotermes curvignathus* attacking *Hevea* and kapok in Java, *C. truncatus* attacking eucalyptus in the Seychelles, and *C. acinaciformis* on *Citrus* and grape vines in Queensland.

In the more arid parts of Africa and Asia, harvester termites belonging to the closely related genera *Hodotermes* and *Anacanthotermes* compete with domestic animals for the scanty grazing.

Throughout tropical Africa there is a large, if highly variable population of termites in the soil, most of which are looking for plant residues on which to feed. Any plant diseased beyond the point of recovery stands a good chance of being eaten up by termites. This scavenging rôle is one of considerable ecological significance, but not one for present discussion. Physiological disturbance from drought or waterlogging will kill a plant, but who can say that it has always passed the limits of recovery before termites take over ? There is no doubt whatever that injuries due to careless hoeing or pruning that would not themselves prove fatal are exploited by termites. Young cotton plants are killed by having their roots chewed by a *Microtermes* in the Gezira area of the Sudan, while similar damage by species of *Ancistrotermes* is observed at intervals in Uganda, Tanganyika and Nyasaland. At the other end of the life of a plant, the onset of maturity may lead to termite attack, as was found by the Tanganyika groundnut scheme. While the men were waiting for enough of the crop to be ripe enough for mechanical harvesting, the termites dealt with the early ripening groundnuts and seriously reduced the yield. In many places, the planting out of young trees is made difficult and in consequence the cost of establishing plantations is greatly increased by termite attack. The case of clove planting in Zanzibar provides an example of this, but any colonial forest department could supply instances of abnormal losses of young trees directly attributable to termite damage.

Discussion

The CHAIRMAN suggested that the discussion should be confined to the aspects Mr. Harris had dealt with, the effect of termites on living plants, and their effect on the fertility of the soil, in relation to which he would like to hear about physical characters as well as chemical ones.

Dr. G. A. PATEL said that the termite problem was extensive in India. As regards the relation of termites to living plants, the damage reported was largely confined to a few crops, notably cotton, tomato and egg-plant. If these plants were examined at the time when they were dying off, they did not show injury by termites, and the plant pathologist said that a fungus was the cause. Termites, however, entered the plants at a later stage and might be the ultimate cause of their death. It had not been definitely proved whether the termites killed the plants or the extent to which the root-rot or foot-rot fungus was pathogenic. It appeared, therefore, that investigation of the relation between damage by termites and damage by fungi was required, and an essential preliminary for this was the finding of a method by which termites can be easily reared.

Mr. C. R. WALLACE, referring to the Chairman's request for information on the effect of termites on the physical properties of soil, said that the substance of termite mounds in parts of northern New South Wales was a favourite material for the construction of hard courts for tennis, and contractors would send vehicles many miles to obtain it.

The CHAIRMAN pointed out that it had been suggested that termites were the tropical analogue of earthworms.

Mr. E. A. ANDREWS said that when he had been concerned with tea plantations in north-eastern India some years ago, he had observed that the plants would never grow on termite mounds, a fact that caused much trouble, especially on experimental plots. Tea required soil with a pH of not more than 5·6, while that of the soil in the mound was always 6–7. He was not aware of any actual accumulation of calcium carbonate. The termite concerned was believed to be *Odontotermes obesus*. The texture of the soil of the mound corresponded with that described by Mr. Wallace, and was similar to that of lateritised soils of southern India.

Mr. M. E. SOLOMON, referring further to the question whether termites attack living plants, said that he had once lived in the hills in Western Australia, 20–30 miles from the coast, near Perth. Many different fruit trees were growing in an orchard there, and termites, which were abundant, regularly attacked dead wood. They attacked a few old trees that were still bearing useful crops of fruit, so that these were broken down by the wind, but he had never observed that they damaged any tree that had no dead wood.

Dr. E. S. NARAYANAN said that termites were important pests of wheat and sugarcane in India, but little was known of methods for their control. Progress in their control would depend on a study of their biology, and though this had been undertaken, it was hampered by the lack of a suitable rearing method. A large collection of Indian termites was available at the Forest Research Institute at Dehra Dun and at the Agricultural Research Institute, New Delhi, and exchange of material or information with other countries would be willingly undertaken.

Dr. R. C. FISHER said that the gradual extension of the range of dry-wood termites, to which Mr. Harris had drawn attention, raised economic problems to applied entomologists, even those in the United Kingdom, whose advice was sought by firms with overseas contracts as to the need for and types of preservative treatment of woodwork or structural timbers to be used in subtropical or tropical countries. The occurrence of termites in desert areas raised similar problems in countries where extensive development schemes were in progress. He would be glad to hear Mr. Harris' comments on the practical significance to the architect, builder and manufacturer of these most interesting data on the distribution of termites.

Mr. W. ALLAN asked whether something good could be said about the soil termites, in that they might perform a beneficial rôle in the soil complex. He had the impression that termite mounds *in situ* were in general more fertile than the surrounding soil. Many native peoples considered that they were, and they were often used in transitional agricultural systems as subsidiary gardens for crops that required soil of high fertility. It was also his impression that termite damage to living crop plants generally, if not invariably, followed some other injury, though this injury would not, in many cases, have caused the death of the plant by itself.

Dr. K. R. S. MORRIS said that in West Africa old termite mounds were frequented by antelopes and elephants in savannah country, because of the food and shelter provided by the thickets of various trees that grew on them. In this respect, it did appear that the soil of termite mounds encouraged and supported a richer vegetation and with it a richer fauna than the surrounding terrain.

Mr. M. H. BREESE asked Mr. Harris how widely occurring was the phenomenon of termites apparently attacking healthy wood. In East Africa one was often presented with damage by termites to apparently healthy wood of tea or tung, but the idea that they did not attack healthy wood was so firmly entrenched that one tended to look for suboptimal growing conditions or evidence of damage before attempting to protect the trees.

Mr. HARRIS said that whether termites attacked healthy wood depended on what was meant by healthy wood. It was doubtful whether ability to identify the disease or other cause that might render wood susceptible to damage by termites was equal to ability to identify the damage they caused. With regard to whether anything good could be said for termites, he thought that there was a lot. They certainly got rid of a great deal of rubbish, and it was difficult to imagine the condition in which tropical Africa would be in if they did not. With regard to Dr. Fisher's question, the relation between entomologists and architects or builders had been discussed at the 1935 Conference. In Ceylon, Dr. Jepson was called in only after termites were established in buildings. He answered questions about them, but the reforms he suggested were not put into force. Old builders would not change their methods, though younger ones might. With regard to soil fertility, the mounds built by fungus-growing termites were made of subsoil and would be more fertile than the surrounding soil if the fertility of the subsoil was greater. This would be the case where leaching of nutrients from the top soil had occurred. Termitaria would thus be more alkaline if the subsoil was more alkaline. One of the reasons why Africans grew crops on termite mounds might be the flooding and water-logging of the surrounding ground; the physical condition of the mound might permit cultivation to begin earlier. He would be glad to accept the offer made by Dr. Narayanan and to exchange material with him or anyone else.

DISCUSSION ON THE DEVELOPMENTS IN LOCUST AND GRASSHOPPER RESEARCH AND CONTROL

Chairman: Professor O. W. Tiegs, F.R.S.,
Department of Zoology, University of Melbourne

The CHAIRMAN expressed his thanks for the honour of having been asked to take the Chair, saying that he was not an economic entomologist, but came from a land where the locust problem was serious. Shortly before he left Australia, they were threatened with a serious outbreak there because the State governments had not taken heed of the entomologists' warning. This meant that they had to face the problem when it arose instead of having prevented it. Two papers would be read at the meeting; one was by Dr. Uvarov, the Director of the Anti-Locust Research Centre, who needed no introduction, and one by Mr. Putnam, who was unable to be present. Both would be discussed together, and he called on Mr. Baird to read Mr. Putnam's paper and to speak first.

Development in Grasshopper Research and Control in Canada

By L. G. Putnam*

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In Asia and Africa, the locust problem, as we understand it in North America, commonly develops as a result of migration by swarms, which can be regarded as coherent units. Present-day grasshopper pest species in Canada are not gregarious in the strict sense of the word, and therefore do not form what may properly be called swarms. Their whole life-cycles are spent in the same, or similar, habitats. On becoming full-fledged, they may or may not migrate; if they do move, mostly by passive subjection to external forces, the distance moved may be short or up to several hundred miles. Usually, flight results not in the transfer of masses of grasshoppers from one place to another, with the density of grasshoppers per unit area remaining approximately constant, but in a sort of dispersal. This is a common characteristic of the lesser migratory grasshopper, *Melanoplus mexicanus mexicanus*. Even when this species penetrated deeply into the prairie provinces of Canada from the United States, as during the 1930's, it appears that the invading body constituted a loose mass or consecutive masses, not swarms. The second important pest species in Canada, the clear-winged grasshopper, *Camnula pellucida*, also may move about by flight, but on a more local scale than the lesser migratory grasshopper. At oviposition time, adults of *C. pellucida* may congregate, but this is probably not social behaviour. It is more likely incidental to the simultaneous choice of restricted oviposition sites by numerous breeding adults. Hatching from the resulting egg-beds produces aggregations of nymphs that sometimes exhibit the characteristics of bands (Criddle, 1933). Nevertheless, their main tendency is to disperse.

Dispersal has not been recognised to occur from areas that could be called " reserves " or " outbreak centres ". In the early stages of grasshopper research in Canada, the outbreak-centre theory was entertained, but it seems to have been doubted just as early (Criddle, 1933). After years of survey and observation, no evidence has been produced to show that outbreak centres exist within the prairie provinces. Some districts are undoubtedly more susceptible than others, but this is a matter of degree. There is no known district or series of districts to which one could direct all control efforts in the early stages of an outbreak with the assurance that this would prevent a general outbreak or arrest its spread. Serious migration and invasion may occur, but when we in Western Canada speak of an outbreak " spreading ", what we refer to in all probability is the spread of conditions favouring the indigenous development of outbreak numbers.

In the prairie provinces of Canada, the grasshopper problem occurs largely when the grasshoppers are in the nymphal stages. It is mainly against this hazard and at this period that money, materials, and time are spent in grasshopper control. The adult grasshopper invades previously uninfested fields and does some damage to maturing cereal, forage, and horticultural crops; this has occurred to a serious extent, but it is always uncertain what damage adult grasshoppers will do to a maturing crop, especially wheat, of which most modern varieties are not particularly susceptible to attack in that stage. Control of adult lesser migratory grasshoppers, normally widely dispersed, would be expensive and relatively difficult. Damage by adults to autumn-sown grains in the seedling stage is another matter, and this can be serious in the rather limited parts of the prairie provinces in which such grains are sown.

The critical elements of the biologies of the main Canadian pest species were discerned early, and seem to have been well understood by Criddle (1921), at the beginning of the first important outbreak on the prairies after extensive settlement and cultivation. All have one-year life-cycles, the egg resting over the long winter period.

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* Co-ordinator of research in the grasshopper project.

The lesser migratory grasshopper lays its egg-pods in soil throughout fields of ripening grain or stubble. It seldom oviposits in tilled fallow lands, of which the acreage is large in the prairie provinces, in marginal areas outside the cultivated fields themselves, or in grasslands. If crop production is attempted on egg-infested fields, it is obvious that the eggs are ideally placed for the emerging nymphs to attack the crop, which may well be emerging at about the same time.

The clear-winged grasshopper often lays its egg-pods in stubble fields, too, but characteristically it feeds in grain fields, or other sources of succulent food supply, and retires to some adjoining dry, sunny spot for oviposition. Such a spot may be the sod or turf area of a roadside or verge, an overgrazed small pasture, the bank of a slough, creek, or coulée, or a barnyard. Concentration of the egg-pods, together with a tendency toward uniform spring development of the embryos, results in concentration of the newly hatched nymphs in the following spring. The impact upon seedling crops, during the nymphal stage, depends largely upon this element of concentration and the habit of breeding in ground immediately adjacent to fields in which grain crops will be sown. Young nymphs of this species may move into a seedling crop in an assaulting wave, eat the crop to the ground and keep it eaten down until the plants die, and move fast enough to emarginate the crop deeply before control measures are applied.

Thus, as Buckell (1937) pointed out, the present-day grasshopper pest species of the Canadian prairies are dependent to a large extent on cultivation and crop production as ecological elements that permit their development to outbreak numbers. This is not true of the interior of the mountainous province, British Columbia. Oddly enough, the same species, the clear-winged grasshopper and the lesser migratory grasshopper, develop as pests on the native grazing lands of the interior plateau of British Columbia; this seems anomalous, since on the prairies they require that the habitat be modified by cultivation and crop production, However, in certain aspects of physical structure, the grazing lands of British Columbia might be claimed to have more in common with the arable habitat than with the grasslands of the prairies.

In any one susceptible area in western Canada, grasshopper outbreaks do not occur annually, and the factors in the rise and fall of the numbers of grasshoppers are of primary interest. The association of grasshopper abundance with conditions of drought and high temperatures is almost too close to be fortuitous. Most persons who have observed several periods of grasshopper abundance think, therefore, along with Criddle (1917), Parker (1935) and others, that, under Canadian conditions, weather is a determining factor in grasshopper abundance. For a number of years, Canadian entomologists have been collecting data of a kind that might be used in the investigation of the effects of weather on the rise and fall of grasshopper populations. This should soon produce a formal demonstration of what has been suspected about this relationship. Such a demonstration in mathematical terms should provide a useful tool for the planning of surveys and the preparation of forecasts. In addition, quantitative data are available to show how, in western Canadian latitudes, moist and cool weather retards the embryonic and nymphal development of grasshoppers, thereby reducing their capacity to increase.

There are one or two things that can be done to counteract drought. Sometimes there is an opportunity to circumvent drought by irrigation. In western Canada, the existing irrigated habitats in general do not seem to permit the development of grasshoppers to outbreak numbers. Irrigation is increasing in extent, and the increase will undoubtedly continue, but irrigating all the potentially irrigable land will not substantially reduce the area subject to grasshopper outbreaks. Secondly, agricultural communities are now beginning to give serious support to experimental schemes for increasing rainfall. Farmers are not primarily motivated in this by the hope of grasshopper control, but if some of the hypotheses presented here are correct, a large measure of grasshopper control would be obtained by increasing, through management, the amount of precipitation over that which would fall naturally in dry years.

If it were not for the major influence of weather, biological factors might intervene to check grasshopper abundance. At least one internal parasite and several very important predators of eggs occur in the prairie provinces. There are several parasites, mostly dipterous, of the nymphs and adults. It is now known that these exert a continuous pressure on grasshopper populations during the mobile stages. At least one fungous disease, caused by *Empusa grylli*, is capable of reducing the numbers of some species dramatically. Predators of the nymphs and adults are potentially important, but largely unevaluated. However, certain species of gulls are numerous near inland bodies of water, and they have been known to destroy local infestations.

Grasshopper parasites have been studied in Canada for several years. The Sarcophagidae and related groups have received the most attention. Their total effect on the pest species has been reasonably well evaluated through a period of grasshopper abundance and scarcity. Thus far, related parasite species introduced from other countries have not changed the situation. The value of parasites as factors in the natural control of grasshoppers seems to depend on the density of their hosts, although the final analysis of data now available on this point is still awaited; it is nevertheless clear that the grasshopper problem might easily be much worse without them. There is an interest in management practices that would favour parasites, and some work has been done on the field biology of the adult stage, but this produced nothing constructive and is not active now.

In western Canada, egg predators appear to be roughly equal in importance to the parasites of nymphs and adults. Although some work has been done on the important Bombyliidae and Meloidae, these projects are inactive now. One of our workers maintains an active interest in the Carabidae. Thus far, work on all these families has been an investigation of what happens under existing conditions, and has not resulted in suggestions for improving their efficiency.

There has recently been increased emphasis on investigations of diseases of grasshoppers, both on the study of the fungous disease caused by *Empusa grylli*, which has been of obvious importance for a long while, and on the search for and development of new pathogens. This is currently a highly active project.

In the prairie provinces, the protection of crops from grasshopper damage is greatly facilitated by the forecasting of outbreaks several months in advance with reasonable accuracy. Because grasshopper outbreaks are associated with arable land and therefore with human settlement, all potential outbreak areas in the prairie provinces are accessible via an intensively developed road system. On the prairies, it is therefore possible to conduct surveys, which can be as thorough as transport equipment and manpower permit. In addition, the grasshopper habitats permit relatively easy quantitative evaluation of both the adults and the eggs by routine sampling procedures. Forecasts are based upon the results of these surveys. Modern survey techniques, and methods of using the resulting data for preparing forecasts, were developed in the 1930's, and have been little revised since. However, efforts are now being made to describe the distribution of grasshoppers and their eggs in mathematical terms, which should lead to more accurate forecasting.

Western Canadian entomologists have never abandoned the hope of controlling most grasshoppers by management practices. The fact that grasshoppers, except occasional invaders, are intimately involved in the same habitat as the threatened crops throughout their life-cycles invites attention to the possibility of control by management, including cultural methods. Fortunately, the agronomic practices of the areas subject to grasshopper outbreaks are in some respects incidentally adapted to control of the lesser migratory grasshopper. The standard practice in such areas is the two- or three-year crop rotation system. In one case half, and in the other one-third, of the land lies in fallow, under intermittent cultivation, for an entire growing season. This land remains free of egg infestation. Of the remaining land, all potentially infested by the end of the growing season, either none, or only one-half, will be sown to crops, since all or half of it will in turn be retired to fallow for the next season. Therefore, if grasshoppers in the infested stubble can be either prevented from hatching or, once hatched, kept out of the uninfested adjoining crops, stubble fields can, in a sense, be turned into traps for the lesser migratory grasshopper.

Tillage methods have long been recommended for the control of grasshoppers in the egg stage: in earlier times, deep burial of eggs with the mouldboard plough; more recently, the surface-tillage procedures now in general use on the prairies. The surface-tilling implements were supposed to work their effect through exposure and " breaking-up " of egg-pods. It now seems clear that much of the effect is, or may best be, accomplished through starvation resulting from removal of all green growth on the soil surface at the time the grasshoppers hatch. Tillage for this purpose is usually too late to prepare land for seeding the same year, but may easily be integrated with the standard fallowing procedure. The method of starvation control came out of experiments with tillage for control in the egg stage. It can be easily adapted to the normal fallowing procedure, because agronomists now recommend that tillage for fallowing begin as early as possible, for maximum moisture conservation.

At present, there is some interest in research on the ecological approach to grasshopper control. For example, there is a current tendency for the establishment of field shelter-belt systems on the more nearly treeless parts of the prairie provinces. It is interesting to contemplate what the effects of these might be on existing pest grasshopper, species. In respect of the species for which field borders, such as roadsides, constitute an important part of the habitat, there is some reason to think that certain modifications may already have locally disturbed the environment. These modifications are associated with road-building and changes in farming practice that have followed upon removal of fences. There is a project to investigate their effects on grasshoppers.

Chemicals have always been used in control campaigns in western Canada during modern times. Arsenicals and fluosilicates were used first, in baits. The large volume of poisoned bait required during an extensive outbreak, the large sums of money required for its purchase, preparation, and distribution, the time required for its application (a disagreeable activity), and its occasional mediocre effectiveness directed much research toward the improvement, cheapening, and more effective use of baits. It was important to find ways to reduce the cost of bait at an early stage, and this was rather quickly done by the discovery that some of the more expensive and scarce ingredients might be omitted or replaced by cheaper ones. Further work showed that some of the assumptions about the requirements for the effectiveness of baits, on the basis of other observations on the habits and activities of grasshoppers, were not necessarily correct. It was found, for example, that grasshoppers would eat dry baits, and would eat all baits under less restricted conditions than had been supposed. Chlorinated hydrocarbons, such as chlordane and aldrin, replaced inorganic poisons in baits almost as soon as they appeared in commercial quantities; a few simple experiments were sufficient to indicate the adequate, if not superior, effectiveness of baits poisoned with the organic insecticides. Investigations on the use of the organic poisons in sprays and dusts began as soon as these poisons appeared, so that, when the poisons were available in sufficient quantity, and as soon as many farmers owned their own spraying or dusting equipment, recommendations were available for the efficient use of the new poisons in these media.

Important work has been and is being done in Canada on other aspects of the biology of pest grasshopper species. In the egg stage, water relationships, temperature relationships, and embryological and diapause phenomena have received much competent attention; together with information from analogous work done in other parts of the world, the results have assisted in understanding grasshopper phenomena. Investigation of the behaviour of some of the pest species has recently been undertaken, including studies on the dispersal of nymphs over barren and vegetated habitats. This has led to detailed laboratory work, at present in progress, on the reactions of grasshoppers to relative atmospheric humidity.

The nutritional requirements of grasshoppers have been studied for several years, both quantitatively and qualitatively. Total food requirements have been investigated both in the laboratory and in the field. The value of a number of common plant species as foods for grasshoppers, from the point of view of their growth, survival, and fecundity when fed exclusively on any one of these species, has been also studied. Research on the effect of within-species variation of plants on grasshoppers is now in progress; it leads on to the consideration of what factors make a plant species favourable for a given grasshopper species. One hope of this investigation is that it may lead to the breeding of grasshopper-resistant varieties of cereal crops.

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Present Trends in Locust Research

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The essence of most problems of applied entomology is the existence of fluctuations in the economic importance of an insect pest. Such fluctuations are particularly obvious in the case of locusts, a term that is here restricted to Acrididae with swarming habits. While in the case of many other insects, the problem is mainly one of periodic changes in numbers within a definite area, locusts present a more complicated picture, since the dynamics of their plagues have three aspects: (1) fluctuation in numbers; (2) changes in the extent of the populated area; and (3) qualitative differences between non-swarming and swarming populations of the same species. The effects of these three sets of phenomena on the dynamics of locust populations are closely interwoven, but they have to be investigated separately, before a synthesis can be attempted.

Numerical Fluctuations

Quantitative studies on locust populations have long been neglected and are only just beginning. This has been due, not to the lack of realisation that such studies are essential, but mainly to the special difficulties in the numerical assessment of locust populations. Any method of direct counting, either of adults or of hoppers, is liable to an unknown and variable error due to changeable response of the insects to disturbance, depending on their age, weather conditions, height and density of vegetation, etc. Some of these factors can be taken into account and suitable corrections worked out empirically, but it will require a great deal of research to evolve really reliable methods of estimating locust populations in absolute figures per area. Such methods would have to be particularly exact in the case of very low populations, where even small errors might lead to wrong conclusions.

Another complicating factor is that most locust populations have an uneven distribution, distinct, though sometimes very loose, grouping of individuals being their common feature. Therefore, the translation of any sampling data into numbers per area unit cannot be a simple procedure, and the statistical methods to be used require a very thorough study.

Finally, even hopper populations are known to be mobile, while populations of adult locusts are notoriously so, as will be discussed later. The obvious effect of this mobility is that the population of a given area, even a relatively isolated one, may fluctuate numerically from week to week, owing to movements in and out of the area; or, it may appear to be stable when the numbers coming and going are balanced, but such an assemblage of continually changing individuals cannot be regarded as a single population.

Great as such difficulties are, they are not unsurmountable, and the methods of estimating locust populations are now being actively investigated.

Even with the present methods, supplemented by non-quantitative studies and observations, it is possible to envisage the most likely factors affecting fluctuations in locust numbers.

The positive effects of the rate of multiplication are certainly of the greatest importance. Evidence with regard to fluctuations in the reproductive rate of locusts in the field is only circumstantial, but laboratory studies on their fecundity leave no doubt that environmental factors cause very great variation in the rate of sexual maturation, the length of reproductive period, and the number of eggs per female.

The rate of survival of eggs is the next critical factor. In the tropical locusts (*e.g. Schistocerca*, *Locusta*, *Nomadacris*), the egg period is a short one, but the range of favourable incubation conditions is not wide, and a high hatching rate depends on suitable temperature and soil humidity during the period.

Negative controlling factors are known somewhat better, merely because their effects are more noticeable. In the case of eggs, high mortalities due to obviously unfavourable incubation conditions have been known to occur; what the rate of mortality is likely to be in less extreme cases will be difficult to ascertain, especially in the case of locust populations of low density when the discovery of egg-pods in the soil is almost subject to chance, and reliable sampling techniques have yet to be investigated.

Egg mortality due to biological causes may be serious locally, but its general effects in controlling locust populations must be judged in the light of the mobility of adult locusts, since the oviposition areas of successive locust generations are seldom the same, and the parasites, predators or disease organisms of one generation are liable to be left behind by the hosts. There is evidence, however, that biological controlling factors may occasionally play a dramatic part amongst egg-beds deposited by swarms; it is of interest to note that this has been observed to happen even in the areas not previously invaded by locust swarms, which suggests that the parasites (*e.g. Stomatorhina lunata*) may have been already living there on other hosts (grasshoppers). Such occurrences are, however, local and their effect on the general course of a plague cannot be easily estimated.

Similarly, the effects on local high infestations of hopper bands and adult swarms of insect parasites and diseases, as well as often spectacular predation, *e.g.* by birds, should be judged in relation to the total swarming population involved in a plague. On the other hand, special attention must be paid to their effects on locust populations at the beginning of swarming, when small initial concentrations might be more susceptible.

The first step in the study of biological controlling factors must be, of course, their extensive survey, since parasites, predators and diseases of tropical locusts are known only from almost incidental records, and such a survey has been initiated.

Quantitative population studies during a plague, when large numbers of swarms are present over vast regions, obviously demand an approach different from that in the case of non-swarming populations. This problem is being intensively studied now in the desert locust (*Schistocerca gregaria*). While the general reporting system is reasonably satisfactory, it has to be borne in mind that the number of swarms within a country cannot be obtained simply from routine reports. Such reports contain records of the swarms actually observed at different places in the country during a given period, but a single swarm is likely to be recorded independently on many occasions if it happens to fly over a densely populated area, while the number of swarms in uninhabited areas is likely to be greatly underestimated. The only way to assess the number of swarms is by day-to-day reconnaissance, and recent experience in Kenya has proved that light aircraft can be relied upon to keep track of migrating swarms for a period of some weeks and thus help to establish the actual number of swarms.

The next difficult point is the number of locusts in a swarm. Swarm sizes are now known to vary from a few acres to a hundred square miles, and the same swarm changes its dimensions according to the formation in which it flies, such formation depending primarily on weather conditions. The density of locusts in a flying swarm also varies widely, and the estimation of locust numbers in a swarm therefore becomes a problem of unusual complexity; the attention of research workers is now concentrated on investigating the methods of such an estimation. Reasonably reliable measurements of swarms in flight can be made by timed aircraft traverses, while densities in them can be estimated from series of vertical photographs taken from the ground. Accumulation of such data should in time make it possible to express the intensity of an invasion in, at least, approximate quantitative terms and to compare total populations of successive generations.

Fluctuations in Area

Extensive migrations of locust swarms are taken for granted and their seasonal character is well established, while recent research has served to provide an objective approach to their analysis on the basis of synoptic meteorology. The evidence accumulated with regard to the desert locust indicates that swarms produced in one area may travel over distances of up to 3,000 miles during a season lasting 2–3 months. As locusts may mature and repeatedly lay eggs during such migrations, the resulting progeny would consist of many populations spread over a vast region; a quantitative comparison of the two generations in an extreme case becomes almost out of the question, although such comparisons are obviously essential for understanding the dynamics of a plague.

Apart from seasonal migrations, which tend to follow a certain pattern, and as a cumulative result of them, the invaded area tends to increase as the plague develops. Historical data so far analysed have shown the gradual expansion of the regions invaded by the red locust (*Nomadacris septemfasciata*) and the African migratory locust (*Locusta migratoria migratorioides*) from the small initial outbreak areas over most of the African continent. The analysis of the two last plagues of the desert locust also provides evidence of some expansion of the plague from year to year, with the occupation of the areas that were previously free.

Since migrations may often lead to an interchange of swarms between the areas, as well as to an overlap of breeding by different generations, only a very detailed analysis of swarm breeding and movements, area by area and season by season, but covering the whole invaded region, can produce a connected picture of the course of a plague. Such a picture will then have to be analysed in the light of detailed weather data, for the respective seasons and areas. This is obviously a long task, but one that must be carried out in order to throw some light on plague dynamics.

The connection that exists between large-scale swarm displacements and the movements of air-masses has most serious effects on the dynamics of locust populations. In the case of the desert locust, for instance, successive generations are usually bred in the geographically widely separated areas of convergence of surface air-flow, which tends to bring rain and locusts at the same time; the success of the breeding depends on the coincidence of both. On the other hand, air movements are known to have caused locust swarms to reach areas in which the weather conditions at the time were unfavourable and even led to mass mortality.

Swarm movements, however, are only a more obvious aspect of locust population dynamics. Much less known is the fact of somewhat similar movements of non-swarming locusts. Movements of scattered hopper populations on an ecological scale, *i.e.* from one habitat to another, cause complications in studies of hopper populations. Even more confusing are the flights of individual adult locusts that are now known to occur on a scale leading to displacements of whole populations for distances up to hundreds of miles. Since in some species such flights occur mostly at night, they sometimes result in most irregular and apparently unaccountable fluctuations in the adult population of an area, and unless the transient composition of such a population is realised, there is a serious danger of erroneous deductions. The problem of movements of non-swarming locusts is at present engaging the attention of field research workers studying the desert, the migratory and the red locust.

Qualitative Changes

There are numerous differences between the swarming and non-swarming phases of locusts, but the only ones that will be discussed here are those that are more directly relevant to population dynamics. In this respect, behaviour differences deserve the first attention.

The essential characteristic of swarming locusts is, of course, their gregariousness. It is sometimes suggested that gregarious responses are a direct and immediate result of population density and that there is no intrinsic difference in behaviour between locusts in the gregarious and solitary phases. Recent experimental work suggests, however, that a mere proximity of individuals does not produce gregarious reactions, unless it is prolonged. In other words, gregarious responses develop as a result of conditioning. It is possible, though not yet proved, that the degree of density and the time needed to produce this conditioning may be different between the locust species, which may also differ in respect of the ease with which gregarious behaviour is lost when the population density is reduced. It is known, however, that non-swarming Acrididae are not susceptible to conditioning by artificially created population density. This is, then, the essential difference between locusts and grasshoppers.

The initial densities required for gregarious conditioning are not likely to be reached in the field by a mere increase in total population evenly distributed over a habitat. On the other hand, there is ample evidence of concentrations of non-gregarious hoppers and adults due to their responses to environmental factors. Such habits as basking on the ground, roosting and feeding on plants, and egg-laying in the most suitable patches of the ground serve to bring together groups of individuals, sufficiently dense to initiate gregarious conditioning. Once the conditioned responses are developed, the groups remain as such even when environmental concentrating factors no longer exist, and hopper bands, or adult swarms change completely the pattern of the population distribution. There is still much to be learnt with regard to the persistence of bands and swarms under the impact of environment, and such aggregations do not necessarily last the whole life-cycle, they may vary in numbers and densities, or they may fuse together or disperse. Nevertheless, their existence cannot be ignored, and it calls for an entirely different approach to the estimation of population of the whole area over which such somewhat fluid groups occur, since it would no longer be reasonable to express it as number of individuals per unit area. Instead, the attention of field workers is directed to investigating the sizes of groups, the numbers and densities of individuals in them, and the distribution of groups in space and time. The statistical problems involved in such a study are very complex and need special investigation by experts.

A consequence of gregarious grouping is that concerted migrations of thousands of hoppers in a band, or of millions of adults in a swarm, are certainly much more important for displacements of large populations than movements of individual locusts. It is entirely due to locust gregariousness, on one hand, and to large-scale movements of air-masses that vast portions of a continent are now invaded by swarms, then left practically free of locusts.

Gregarious life has deep physiological effects, some of them very relevant to population dynamics. Thus, gregarious locusts develop more rapidly than solitary ones, and the rate of development of individuals in a group is synchronised, thus assuring mass reproduction when favourable conditions occur. On the other hand, protracted development of solitary locusts may be a factor extending their individual lives and increasing the chance of the meeting of the sexes even in very sparse populations. An extreme case is parthenogenetic reproduction in solitary females of the desert locust, which are also exceptionally long-lived.

Other physiological effects of gregarious life are reflected in the coloration and morphometric characters of the locusts, which promise to supply the means of reconstructing the immediate history of a population, and particularly of identifying populations. Since phase variation is a reflection of metabolic and growth phenomena, some of which are similarly affected by other factors, a thorough experimental study of these phenomena is one of the major problems of modern acridology.

It will be seen from this necessarily very brief survey that locust research is faced with a formidable array of problems, many of which cannot be solved without close assistance of other sciences, in particular of meteorology and statistics. The earlier methods of simple observation and reasoning are still of great value for raising questions, but more exact techniques of recording data and of analysing them are needed for finding objective answers.

Discussion

Dr. R. S. SCORER said that Dr. Uvarov had challenged meteorologists to take part in the fight against locusts. It was very difficult for a meteorologist to do this unless he had some knowledge of the biological factors that controlled locust behaviour. For example, the density of swarms was presumably important because it was more efficient to attack a given number of locusts if density was high. If biological factors were concerned in determining density, the meteorologist should know about them before he attempted to explain variations in density and then to forecast them.

Mr. Putnam's passing reference to control of rainfall should not be taken too seriously. Canada was not a particularly suitable country for such work, which, if it were attempted, would require the co-operation of the United States on a wide geographical scale. This could hardly be obtained without some change in policy there, because of the widespread, indiscriminate and uncontrolled attempts to modify weather in the United States. Nor were there much grounds for hope of success in Canada even with complete co-operation with the United States.

Dr. UVAROV said that the study of swarm density required a joint meteorological and biological approach; the factors that brought and kept locusts together were of a double nature. Information on synoptic meteorology, supplied by the World Meteorological Organization, was already helping to explain large-scale movements. Changes in density within swarms also involved meteorological factors, such as air turbulence, as well as biological ones. Joint study was essential; the meteorologist alone was helpless and the biologist alone was led astray.

Dr. TASKHIR AHMAD paid a tribute to the valuable contribution made by the Anti-Locust Research Centre in London to research on the desert locust, and to the co-ordination of information on it and of its control. Control of this locust was of the utmost interest to Pakistan, which was invaded by swarms twice in the year, once in autumn from the east, and again in early summer from the west. The control organisation maintained in Pakistan was large—over 200 technical officers, transport, and several spray aeroplanes, including Beavers. Experiments there some time ago had shown that aldrin, previously used as a spray only in oil solution, could be applied successfully in water by emulsifying a solution in it. This had eliminated the high cost of transport into the desert of large quantities of solvents. Hoppers could be effectively controlled by baits of rice husks or bran poisoned with aldrin or, in the first and second stages, by direct application of diluted BHC with road dust.

Dr. J. S. KENNEDY said that, in view of the discussion at and since the last Conference regarding the value of the theory of phases, he would like to reaffirm the view that the phenomenon of phase transformation was not merely, as Dr. Uvarov had called it, a complicating factor in the plague cycle that was characteristic of locust population dynamics, but was of fundamental importance from an economic as much as a theoretical point of view. Locusts were distinguishable from grasshoppers to the extent that outbreaks were literally " breakings out " from the normal habitat as a result of gregarious swarming. Swarming, in its turn, was one aspect of phase transformation, a physiological response to mutual stimulation. Such stimulation occurred when the environment was patchy enough to cause the locusts to crowd into the preferred patches when their numbers increased. Swarming thus constituted a " density-dependent factor " in the classical " controlling " sense of the population theorists, reducing first the local density and eventually the whole population. There was evidence that both phase-physiological causes and immediate environmental causes were responsible for the decline of a swarming population, and also that similar causes acted in the opposite sense to rebuild the population after the plague had declined. The phase or plague cycle appeared to be the natural population-regulating mechanism for these species.

Economically, the evident need was to create another regulating mechanism that would reverse the rising trend of local population density no less automatically than the phase change did, but would reverse it at a lower level, before the density became sufficient to bring itself down by the natural " ejection " mechanism. With locusts, unlike grasshoppers, it was the swarming out that was economically important and not the local build-up of population in itself. Whether a given increase did, or did not, lead through crowding to swarming depended on the effect of environmental influences on the movements of the insects; and their movements also depended on their phase physiology. Locust plagues could not therefore be dealt with as a population problem on classical lines, abstracting population from physiology and movement. Population changes were of course fundamental, but they would be neither understood nor controlled without the closest attention to the phase-physiological changes that played so large a part in them.

Dr. C. H. N. JACKSON said that Dr. Kennedy's view that outbreaks were the mechanism by which the numbers of locusts were reduced applied only to locusts in their outbreak centres, since small colonies of the solitary phase of the red locust occurred sporadically and permanently in various parts of Tanganyika Territory.

Mr. J. A. WHELLAN supported Dr. Jackson by saying that small colonies of the solitary phase of the red locust had existed in Southern Rhodesia, apparently in much the same numbers, for at least 12 years without any possible reinforcement by swarms. It would thus seem that only the swarming phase could be considered as committing mass-suicide, the solitary phase being perhaps capable of indefinite continuance at low density. Dr. KENNEDY said that this was precisely his point of view.

Prof. O. W. RICHARDS felt that the work of the past six years led to the conclusion that phase changes were more a consequence than a cause of changes in numbers.

Dr. UVAROV said that it was an increase in density that led to the change to the gregarious phase. Such an increase had been observed only in environments that were restricted. Numerical data would be needed to show whether a population scattered over an area of several hundred square miles could increase in density to the extent of producing the swarming phase over the whole area, but there was not a shred of evidence of it. Grasshoppers could occur in large numbers over large areas and sometimes in dense populations, but swarming did not occur in them.

DISCUSSION ON THE RECENT DEVELOPMENTS IN TSETSE RESEARCH AND CONTROL

Chairman: Professor P. A. Buxton, C.M.G., F.R.S.,
London School of Hygiene and Tropical Medicine

The CHAIRMAN said that this discussion would be opened by a reading of a paper by Dr. Jackson. This paper would be discussed, and Dr. Nash would then show a series of slides to illustrate a recent method of control that he had devised, after which a short time for further discussion would be available. The subject of Dr. Jackson's paper was an enormous one, and he hoped that those not specifically concerned with work on *Glossina* would not hesitate to take part in the discussion of it.

Recent Advances in Tsetse Research and Control

By C. H. N. Jackson
East African Tsetse and Trypanosomiasis Research and Reclamation Organisation, Central Tsetse Research Laboratory, Shinyanga, Tanganyika

My first Director, C. F. M. Swynnerton, came to Tanganyika to find a more acceptable way of eradicating tsetse flies than slaughtering the game animals on which they feed, and it was his great contribution that he advocated control of the vegetation instead. At Shinyanga, he planned to cut up the bush into isolated blocks by clearings for treatment piecemeal, and though his clearings were, as we now know, too narrow to stop the passage of all flies—something like two miles is needed for that—he did achieve a great initial success. His first step was to explain to the local people that they need not retreat any more before the advancing tsetse, *Glossina swynnertoni*, but should turn out and cut down the encroaching bush as he showed them; and that he would help them to drive the flies out of even the uncleared blocks. He commenced a régime of grass-fire control, with each year a fierce fire on a broad front, preceded by some clearing of thickets and followed by hand-catching and lime-trapping of flies after the fire had swept through. Though these methods are no longer used, they were followed by such a reduction in the flies that native settlers were tempted in, and eventually, by cutting for poles and firewood, by heavy grazing and general disturbance, they did get rid of the flies that were left. It now appears that, in open woodland, sufficient over-grazing will do this by itself; neither man nor cattle seem permanently acceptable as hosts to these flies of the *morsitans* group, for when, in the closing stages of our large-scale game destruction experiment, the country became heavily grazed by cattle in a dry year, they failed to save the flies from extinction—which they may indeed have hastened.

In 1930 we noticed that parts of the bush in Shinyanga that had not been burned for two years had few flies, and later results led us to try the total exclusion of fire. This reduced the commoner Shinyanga tsetse, *G. swynnertoni*, by about 50 per cent. per year; we at first thought we were doing a good deal better than this, because we were unaware that these flies normally fluctuate to a long-term cycle of about 11 years, and we did not know that, when we put in our fire exclusion, they had just passed their last high point. It seems very likely that part of Swynnerton's initial success was due to the same cause.

The fire exclusion not only reduced the flies—we have no idea how it did so—but it concentrated the survivors, more and more, year by year, into short-grassed patches called by us hard-pans, which had been known to be specially favoured years before fire exclusion was thought of. When it became apparent that fire exclusion alone was going to be too slow, and numbers actually turned slightly upwards after the trough of the long-term cycle, we decided to apply discriminative clearing, or, as I shall call it, spot clearing, to the hard-pans only. The immediate effect was spectacular, and further clearings eventually resulted in the complete disappearance of *G. swynnertoni* from the 55 square miles of the block, though the other species present, *G. pallidipes,* continued as before.

Fire exclusion, however, though superficially costing little, in fact demands enormous overheads, including permanent staff available for fire-fighting, and transport, which, at Shinyanga, happened to be in plentiful supply. We therefore tried spot clearing alone, and in several places we were completely successful without any control of fire. The method is first to recognise, in the country to be reclaimed, the type of place where concentrations of non-hungry male flies are to be found, for here, though the females conceal themselves, most of the breeding goes on. When the favoured type of site has been established on the ground, it is very helpful if there is photographic air coverage, as there is in much of East Africa now, so that the known favoured sites can be identified on the photos, and other similar ones recognised. A double set of photos is needed, one for a mosaic map and the other to use loose as stereo-pairs. Sometimes, when spot clearing goes well, less than five per cent. of the area need be cleared, and semi-isolated fly belts, with limited avenues for reinvasion, can be defended, after reclamation, by spot clearing in depth. Regeneration to form a favourable habitat may be very slow; the plant succession tends to get upset, so that trees come on in the wrong order, while others sprout as many-stemmed instead of single-stemmed trees from the cut stumps, and the whole thing takes a very long time to get sorted out again. We in Tanganyika therefore prefer spot clearing to game destruction, as being more permanent; and although we have found, in a large area isolated against reinvasion, that game destruction did eventually get rid of two if not three species of tsetse, we think that it should not again be used, except in isolated areas of manageable extent.

The chief trouble with spot clearing is that, because the flies come to the catchers from some distance, it is not easy to decide just which parts of the woodland are vitally important, or in what way, so that we may often do more, or less, than is needed. We never know beforehand whether or not it is going to work, and success in one country does not mean that the same man can succeed in another. The result is a team of local experts, who do get results but who cannot tell us why, and who cannot with any certainty succeed elsewhere. Possibly the answer may lie in the long-neglected study of fly behaviour in the laboratory, checked back in the field but the end is a long way off.

One method of reclamation-on-the-cheap is the separation of grassy plains from the main tsetse bush. Sometimes the plains are covered with a light network of small acacias and other trees that are always infested with wandering flies, though they are incapable of forming a proper habitat. We have had success, at very little cost, merely by cutting the connections of this tenuous network with the main tsetse bush, and the flies have almost immediately disappeared.

A thing in which we are very interested is the interplay of human settlement with tsetse infestation. It does seem that in some countries, perhaps in many, grain-growing man requires the very spots, chiefly footslopes, that form the best tsetse habitats, so that if we can ensure that new settlers take up every one of these sites, no special anti-tsetse measure may be required. We also notice how in some places the tide of human settlement is flowing against the flies, while in others it is running the other way. This we cannot at present explain, but it is not necessarily a simple matter of human population increase, for sometimes the people can be very much compressed.

I should make it clear, to those who do not know already, that in East Africa our main problem is the flies of the *morsitans* group, which occupy great areas of dry woodland and thicket, and are not dependent on surface water. Further, ours is mainly a cattle problem, for *Trypanosoma rhodesiense*, the trypanosome of human sleeping sickness carried by these flies, though more virulent than that of West Africa, is not found affecting any large proportion of the people, and can be controlled by making them live together, in large units of a thousand families or more, thus breaking the main contact between man and fly. Cases of sleeping sickness still occur when people visit the uninhabited bush, but they can mostly be dealt with by good propaganda leading to rapid treatment, and the number of deaths is small. With us in East Africa, cattle are the important factor, not man.

In West Africa the picture is very different. The disease in man is caused by *Trypanosoma gambiense*, which is a comparatively avirulent, but more insidious parasite, and may affect up to ten per cent. of the population, because people take a long time to die of it. Also, the vectors are flies of the *palpalis* group of waterside tsetses, which thrive in rather than avoid the proximity of man. They cannot be controlled by game destruction, because a large proportion of their food can be drawn from reptiles, which are not used by the *morsitans* group. Though flies of the *morsitans* group do occur in the dry woodlands of West Africa, they are less widespread there, perhaps because the generally higher density of the human population tends to exclude the normal animal hosts. Thus the West African problem is for the entomologist more one of ridding the watercourses of *G. palpalis* and its relative *G. tachinoides*, which are more sensitive to desiccation than *G. morsitans* and its allies.

In Nigeria, Nash has refined the methods of stream and river clearing to eliminate the flies, and has freed very many miles of stream. He is now experimenting with a new method, known as obstructive clearing, which consists in blocking the watercourses with unfavourably dense thicket, induced by removing tall trees that form the top canopy, and tend to keep the thicket suppressed.

In the Gold Coast, Morris conceived the idea of permanent eradication of all thicket-forming species of riverine plants, by systematically digging out their roots from the headwaters downwards, and he did achieve at least near-extermination of

G. tachinoides over about a thousand square miles at very low cost, with drastic reduction in the incidence of sleeping sickness.

Game destruction on a very large scale was applied in Southern Rhodesia, though now some spot clearing is being tried as well. Nearly 10,000 square miles of country were cleared of *G. morsitans*, at the cost of some 30,000 head of animals shot each year. Largely through over-confidence, game and flies have seeped back for the time being, but this need not blind us to the fact of a remarkable achievement, which prevented the over-running of a large area of white and native settlement, when no alternative method seemed to offer.

Moggridge, formerly one of Swynnerton's staff, is now Director of Tsetse Control in Uganda. He faced a serious and worsening situation, with very general advances of *G. morsitans* and *G. pallidipes*, but, with the help of his efficient, well-paid and well-led staff, he has completely turned the tables on the flies, and has freed 6,000 square miles from them. Of this area, 1,700 square miles were freed by spot clearing, and in the remainder the aim has been to sever the relationship between the tsetse and the game. Moggridge first drives " Jeep " tracks through the area to be reclaimed, to allow shooters and surveyors to get in. Then shooting of the game begins, especially buffalo, with special attention to all spots in which flies persist, where eventually he may use bush-clearing to finish them off. A feature of the work is careful day-to-day survey of the situation by cycle teams. Moggridge aims in each area to drive the flies back to a narrow neck that can easily be defended. He rightly emphasises local knowledge, claiming for example that, if *he* finds the buffalo a vitally important host-animal in most of Uganda, it is no refutation to point to the same species of tsetse living without buffaloes elsewhere; we shall do well to remember this, however much we should like more information on the apparent anomaly.

Traps, which, under dry conditions, averaged 70 *pallidipes* each day, with a high proportion of females, were invented by Harris and used in Zululand for many years. They failed to eliminate the flies, and were superseded by insecticides sprayed from aircraft, at a cost of over a million pounds. Complete success was expected by March 1953, but I do not know whether it has been achieved.

You have already heard from Mr. Yeo something of the use of insecticides against tsetse in East Africa. We ourselves tried spraying DDT on bait cattle, putting 30 herds of ten animals into only five square miles of bush. This method greatly reduced the density of *G. pallidipes* almost at once, but there are heavy overheads, and it has never been used on a large scale, though later against *G. morsitans* it seemed especially good. Insecticide trials now are mainly against the riverine species, which cover more manageable areas. In principle, however, I think that insecticides used directly against the flies are wrong; what we need is a really good residual effect on their perching places, even if only in the dry season. To my mind, the fundamental fact arising from all this work is that isolated tsetse populations by no means always tend to recover, when the applications of insecticide cease.

I shall say nothing about biological control, except that it has never shown real promise, and no work has been done on it for 20 years.

Turning now to the small Research horse after the large Reclamation cart—for that is rather the order in which things have been done, which is, you may suppose, why we have not been more effective—I would mention first the work of Nash, who has made a thorough study of the ecoclimates experienced by both adults and pupae of *G. morsitans*, *G. palpalis* and *G. tachinoides*. This knowledge, apart from its proved value in guiding reclamation, is of the greatest use to laboratory workers studying such things as the critical temperature for water-loss, and indeed the whole relation of temperature to tsetse physiology.

Laboratory studies, on both physiology and behaviour, are a very neglected side of research, and one which we are now pushing ahead. Roubaud in French Equatoria, Wigglesworth, Buxton and Lewis in Nigeria, the Mellanbys in Uganda, and later Jack in Rhodesia, have given us, mostly in a few months of work apiece, almost all the basic data we possess.

At 23° C., a common mean temperature in East Africa, the first egg is ovulated, always from the right ovary, 12 days after emergence of the mother; it is then fertilised, and the larva hatches three days later. It moults twice in the uterus, at first subsisting, and growing considerably, on yolk from the egg, but later taking milk from special glands; it is full-grown in about a week. It is extruded in a shady place, and the mother endeavours to find friable soil in which it can burrow, but on very wet soil it may pupate on the surface. It is negatively phototactic. The pupal period is 33 days for females at 23°, varying from 21 days at 30° to 130 days at 14°.

The sexes are produced in equal numbers, and the interlarval period at 23° is 11 days. As the first larva takes about 23 days, a mean female life of two months would suffice to produce four larvae, which would allow a 50 per cent. mortality in the early stages, leaving one male and one female to carry on the race. Though lucky females live very much longer, and produce as many as 15 larvae, I believe that two months is perhaps their average life; males, though they also can survive over 100 days, seem generally to live less than a month.

This conclusion comes from marking and recapturing flies in the field, from which also data on absolute numbers are obtained; true densities can then be compared with apparent densities, namely numbers caught per unit distance, to give comparative availabilities, which are found to vary from species to species by as much as 50 to 1.

In nature, tsetse flies feed about every fourth day at 23°, but they feed more often in the laboratory, where they do not do well. They do not digest their meals properly, they fail to synthesise much fat, and their offpsring become smaller from generation to generation. Until all this is put right, a certain amount of suspicion clings to most laboratory findings because the subjects are abnormal.

It appears that some species have feeding grounds to which they are led when hungry, and where they are likely to meet with host-animals, especially in the dry season, when water-loss, which must be made good from a blood-meal, is severe.

Until recently, we knew little about their host-animals, except that the *morsitans* group took mainly mammalian blood, but now Weitz of the Lister Institute, working with wild animal bloods collected by us, has perfected a technique that actually allows him to distinguish, in the wild tsetse, day-old bloods of species so closely related as horse and donkey, or bush-pig and domestic pig. Provisionally, *G. morsitans* seems to feed far more on pigs, and far less on Bovids, than most of us would have guessed.

In such a short time I can do no justice to trypanosomiasis work. We have shown that *T. rhodesiense* can be kept going cyclically, through flies and sheep, for 18 years, and still be as infective to man as ever, which suggests that, in the absence of man, it might be able to continue indefinitely in the wild game. We are greatly interested in the reasons why different flies carry different trypanosomes; why for example do *G. morsitans* and its allies convey only the virulent *T. rhodesiense* to man, while the species of the *palpalis* group carry the mild *T. gambiense*, although in the laboratory flies of either group can transmit either trypanosome? Among the trypanosomes of domestic animals, of which *T. congolense* and *T. vivax* are the most important, diagnosis in the tsetse is more difficult than we thought, especially since we have realised the abundance of that protean creature *T. simiae*, of which the natural host is wild pigs, as its characters cut right across the usual definitions of *T. congolense*, *T. vivax* and *T. brucei*. Now also the Belgians, Peel and Chardome, have re-discovered *T. suis* in *G. brevipalpis*; this trypanosome, though monomorphic in the pig, which is its sole vertebrate host, completes its development in the salivary glands of the fly, supposedly the absolute prerogative of the so-called polymorphic trypanosomes, *T. brucei*, *T. rhodesiense* and *T. gambiense*.

Discussion

Dr. K. R. S. Morris said that in the Gold Coast selective clearing of streams and destruction of the fly-belt vegetation had successfully eradicated *Glossina palpalis* as well as *G. tachinoides*, and the completeness of the eradication had been demonstrated by ten years' continuous observations by fly-boys. By 1952, a total area of 3,000 square miles had been freed from *G. palpalis* and *G. tachinoides*; eradication was progressing and was being followed by settlement and utilisation of the river valleys.

G. morsitans had been eradicated as a breeding species from a much smaller area, 200 sq. miles in extent, by human settlement to a density of anything over 15 persons per sq. mile. Research had shown that this density was sufficient to prevent the establishment of *G. morsitans*, which might intrude, but did not persist. The question of human settlement as a weapon against the tsetse was of great interest. In Tanganyika, Dr. McLean and Dr. Fairbairn established effective control of *G. morsitans*, and consequently of Rhodesian sleeping sickness, by the simple method of aggregating scattered villages into communities comprising a minimum of 3,000 people. This measure alone so reduced the fly that the epidemic was entirely checked, and cattle were being reared in the settled areas within 3–4 years. The great advantage of human settlement for tsetse control was that it was cheap, and above all was permanent. It did not require costly repetition, as would control by insecticides. In this way it shared the advantages and future possibilities of control by biological methods.

Dr. J. R. Busvine said that *G. morsitans* had been advancing in 1952 in an area in Northern Nigeria (round the Anchau corridor). A mile-wide barrier had been cleared and DDT fog released. Human settlement was desired to prevent the spread, and the land was suitable for farming except for the local occurrence of *Simulium* and onchocerciasis. He asked what was the present position.

Mr. R. J. Kernaghan replied that in the past two years there had been no major extension of this advance of *G. morsitans* in Northern Nigeria. It was probable as suggested by Dr. Jackson that it had in some places food-hosts other than those usual in other places, such as the large game animals, which were very scarce in Northern Nigeria. A game bounty in a *morsitans* area in Nigeria produced only the smaller antelopes.

It appeared that there was a definite future for insecticides against the riverine species of *Glossina* in Northern Nigeria. An isolated population of *G. tachinoides* had been eradicated by one application of a 5 per cent. DDT spray. The insecticide was in the form of a wettable powder and persisted on foliage for at least eight weeks, roughly equivalent to the pupal period, during the dry season.

Mr. B. J. A. Nowosielski-Slepowron stressed the value of traps as a method of sampling for species of *Glossina*. The use in the Gold Coast of a trap designed by Dr. Morris had shown the presence of more species than were found by fly-boys and the occurrence in considerable numbers of supposedly rare species. Thus *G. palpalis*, *G. nigrofusca* and *G. pallicera* were all trapped in a year in an area in which fly-boys found only *G. palpalis*; and five species, *G. palpalis*, *G. longipalpis*, *G. medicorum*, *G. tabaniformis* and *G. nigrofusca*, were all recorded in traps at a place on the coast where the only species taken by the fly-boys were *G. palpalis* and, in small numbers, *G. longipalpis*.

Dr. T. A. M. Nash said that attention in Nigeria used to be focused on riverine tsetses, because of the high incidence of sleeping sickness, but that the problem of *G. morsitans* had been coming more and more to the fore since the end of the war, owing to the new settlement schemes that were being started, often in *morsitans* woodland.

Mr. W. H. Potts congratulated Dr. Jackson on his able and comprehensive survey, but thought that he had been a trifle modest in his mention of work on population estimation, pioneer work for which he had himself been almost entirely responsible. It was of fundamental importance, not only for tsetse control (since it is obviously necessary to be able to estimate total populations before and during operations), but also from a general biological point of view.

He wished to ask Dr. Jackson about one small point, in connection with his remarks on the disappearance of tsetse as a result of entry of cattle and consequent overgrazing and trampling of bush. Dr. Jackson had suggested that the entry of cattle at the conclusion of the game-destruction experiment at Shinyanga had driven out the fly. But surely in this instance the tsetse had already virtually disappeared as a result of the extermination of their normal food-hosts, and it could only be said that the cattle did not allow the remnants of the population to survive, multiply and reinfest the area.

Dr. Jackson agreed that there was no evidence in this instance that the cattle drove the flies out. In just one case, however, it really looked as though they had. The species concerned was *G. pallidipes*, which was present in an area near Shinyanga where cattle were grazing quite a lot, but of which neither adults nor pupae could be found where the cattle grazed heavily.

Dr. Nash then showed the series of slides, to which the Chairman had referred, in order to illustrate experiments that he was carrying out in Nigeria, with the object of evolving an entirely new method of riverine clearing for the elimination of *Glossina palpalis* from the streams that are its habitat. The method was termed " obstructive clearing " because its aim was to alter radically both the environment of the fly and its behaviour, by obstructing its flight-line along the shady stream bed and so forcing it to search for food in the adjacent savannah, where the climate was seasonally insupportable. The obstruction was produced by felling the trees of the high canopy so that they fell actually into the stream. It was stressed that the method would probably be of no value against *G. tachinoides*, but that there were huge areas of West Africa in which *G. palpalis* occurred and *G. tachinoides* did not.

The method was designed to supersede the current one of partial clearing. The latter consisted in felling the thicket and low-branching trees along the part of the stream to be cleared and leaving the tall clean-boled trees. This permitted entry of the hot dry harmattan wind, which so altered the ecoclimate and microclimate that the fly was eradicated. As, however, the conditions produced were effective only during the dry season, wet season invasion from the riverine vegetation at the uncleared ends was prevented by ruthless barrier clearings, each one mile long.

If successful, the adoption of the method of obstructive clearing would effect a considerable saving in costs. It was found that the expenditure in man-days required to carry it out was a little less than half the average required in the Anchau partial clearings, and it would obviate the need for annual re-slashing, the supervision of which had become an almost intolerable burden in Northern Nigeria, owing to the enormous mileage of river that had been cleared by the Sleeping Sickness Service.

In the experiment cited as an example, obstructive clearing was applied along a two-mile stretch of stream that had been isolated by a ruthless barrier clearing at each end. All the tall trees other than the " giant emergents " were felled, except where the riverine vegetation was so thin that it could be seen through, and where fords had to be left open. In this way, the high canopy was destroyed and the flight-line of the fly was blocked, the stream-bed being choked with trees and branches, which were gradually overgrown by creepers. Readings from the meteorological screen showed that the microclimates in the stream-bed did not become unsuitable for the fly and so could not have been a factor in the results of the experiment. The stream never dried up.

The experiment was begun in February, and it was hoped that the tsetse population would be rapidly exterminated, as the flies would be forced to roam through the savannah at the hottest time of the year in search of food. Unfortunately, three herds of Fulani cattle were brought to the area in January and did not leave it until six weeks after the rains started in April. They were grazed daily along the banks of the streams during this period.

Despite this, the reduction in fly population was drastic. The average density (number of flies per boy per 1,000 yards) followed the expected seasonal changes in a control stream, falling from 6·0 in January to 4·2 in April and rising to 13·0 in June, whereas the densities in the treated stream were 8·6 in January, 0·6 in April and 0·7 in June. June was the last date for which figures were available; an uncontrolled population could be expected to reach a peak about September. Thus the destruction of the overhead canopy and the blocking of the flight-line apparently caused a great reduction of the population during a period of normal decrease, and kept it virtually static during a period in which the population in the control stream trebled itself and became 19 times as great as that in the treated stream. In practice, nothing short of eradication would suffice but there were still hopes that this might be achieved.

In reply to questions by Mr. M. E. SOLOMON, Dr. F. I. VAN EMDEN and Mr. POTTS, respectively, Dr. NASH said that there was no evidence that the blocking of the stream made the water unfit for drinking; that any effect it might have on the breeding of mosquitos was unknown—there would still be heavy shade, although it would be low instead of high; and that only time would show whether it would result in any alteration in the course of the stream with consequent changes in the surrounding country.

APPENDIX V

MEMORANDA SUBMITTED IN CONNECTION WITH OPEN MEETINGS

A. MEMORANDUM ON COMMONWEALTH RESOURCES FOR THE IDENTIFICATION OF INSECTS OF ECONOMIC IMPORTANCE

Prepared by

THE COMMONWEALTH INSTITUTE OF ENTOMOLOGY

In 1952 the British Commonwealth Scientific Conference held in Australia recommended that the Commonwealth Agricultural Bureaux should examine the supply of taxonomists in or available to the Commonwealth to permit the identification of all groups of organisms of importance to agriculture (B.C.S.C., Australia, 1952, Recommendation 9). The Commonwealth Institute of Entomology was asked to consider the matter as regards the groups which are its concern, and the Director as a first step circulated a letter to the chief entomologists of the various Commonwealth countries, and to the Colonial Office, setting out the problem and seeking comment on certain aspects of it.

It was pointed out in this letter that the acute shortage of experienced workers engaged in taxonomic research is common knowledge, and that it is against this background that one must view the Commonwealth's resources for the naming, in its limited sense, of economic insects. The principal considerations were set out as being that the field is so vast that the help of numerous specialists in particular groups must be enlisted, that discretion is needed in utilising their services, that in certain groups or sections nobody is working, and that many capable specialists avoid identification work because it hampers them, or only accept material for future study. It was concluded, therefore, that a mere list of specialists would be of little use and that to be of value it must be restricted to those who are experienced, reliable and able to deal expeditiously with material received.

It was suggested that a discriminating and comprehensive list could best be prepared, and used, by a central organisation with long experience, which might gain a more satisfactory response from specialists than would a direct approach by workers seeking identifications. The Commonwealth Institute of Entomology represents such an organisation. While, however, its identification service is believed to be, in general, sufficient for the needs of the Commonwealth other than those satisfied by the identification facilities available within the member territories, it was thought desirable to seek the views of Commonwealth entomologists on the general problem of taxonomy in relation to the identification of insects of economic importance and also on the two specific points:

(1) Whether existing taxonomic and identification services are considered adequate by agricultural entomologists.

(2) Whether there are experienced taxonomists in the Commonwealth who would welcome, for identification or research, more material from other Commonwealth countries than they already receive.

Replies to the Director's letter were received from Australia, Canada, Ceylon, India, New Zealand, Pakistan, Southern Rhodesia and the Sudan, in addition to some received through the Colonial Office. These replies are analysed below.

Appreciation was generally expressed of the identification services rendered by the Commonwealth Institute of Entomology. Some sympathy was felt for the field entomologist who is unable to obtain specific identifications for some of his material, though it was realised that an expansion in the numbers of people engaged in identification could scarcely meet the problem presented by such countries as Australia, for which present identification and taxonomic services were described as grossly inadequate in view of the fact that the major groups of Australian insects are insufficiently known.

It was made clear that there exist no untapped resources of taxonomic workers in the Commonwealth. In Canada, Australia and New Zealand, taxonomists are fully occupied with material from their own regions and are unlikely to be able to take on material from outside, except in the case of some Canadian workers who might be able to cooperate in generic studies on a Nearctic or even world basis. Much the same may be true of South Africa. In India and Pakistan there are relatively few taxonomic workers, and these are confined to scattered groups and to the Indian region. Elsewhere in the Commonwealth there are, outside the United Kingdom, no entomologists engaged in taxonomic work other than in certain restricted problems of local importance. The view thus seems to be confirmed that, for the Commonwealth as a whole, the maximum resources at present available for identification are already being used.

The view was widely expressed that, although an increase in the staff of the Commonwealth Institute of Entomology was very desirable, the identification services in general could not be strengthened merely by increasing the number of people engaged in routine identification work and that the fundamental necessity was an increase in critical revisionary work. It was felt that this must necessarily continue to be mainly the responsibility of the museums, universities and research institutes: at the same time it was recognised that, though some specialists might welcome material for identification in their own groups, many might well prefer only to acquire material until they could revise a group, and would not wish to be over-burdened by continual small lots of specimens for special attention, particularly if not in the group they were working on at the time.

Various suggestions were put forward for improving taxonomic work. It was commented that systematics, belying its name, is a haphazard subject, both as regards the distribution of workers amongst groups and as regards the qualifications of the systematist. Adequate professional training is required, but is hardly anywhere provided, to produce taxonomists and curators. Some tightening up of organisation is desirable, if possible on international lines. These comments, in fact, while recognising the over-riding need for more taxonomists, imply that a survey of existing ones might draw attention to groups which particularly need reinforcement. More than one person, for example, pointed to the need for more workers in the parasitic Hymenoptera, and a particular gap mentioned is the lack of means of identifying more than a fraction of the immature stages in nearly all groups of insects.

Apart from the generally expressed view that more taxonomists are required, certain suggestions were made for reducing the calls on existing ones. It was felt that more stress should be placed on the production of keys and of regional compilations, both of which might enable the work of identification to be more decentralised. A suggestion was made from Pakistan that in order to strengthen the identification services in the less developed member countries and thus lighten the load on the central institute, facilities for training in taxonomy should be available at the Commonwealth Institute of Entomology, possibly by such means as fellowships offered under the Colombo Plan. The interpretation and possibilities of implementing such a proposal would need very careful consideration.

To sum up, whilst it was generally agreed that an improvement in identification services can only come about as a result of an increase in the volume and, to some extent, the quality of taxonomic work, no very definite proposals were advanced for fostering such an increase.

There are two reasons for the present inadequacy of taxonomic studies, the first being shortage of money to increase museum staffs, the second being a certain scientific disrepute associated with taxonomic work in the minds of university students and, perhaps, staff. It would, perhaps, be appropriate for the Commonwealth Scientific Conference to enter a plea for the more adequate financing of work in the reference collections of the Commonwealth, so that prospects and rewards in taxonomic research are more comparable with those in other fields. As regards the scientific appeal of taxonomic work, it may be expected that the development of more modern attitudes, linking systematics with genetical and evolutionary studies, and the growing tendency in some Museums and Institutions to send their workers overseas periodically for study or collecting expeditions, will attract young research workers to an increasing extent.

As regards the particular problem of identification of insects of economic importance, as against general taxonomy, it is important to bear in mind that the identification of such material falls into two very distinct categories, one routine and the other long-term work. Material of economic importance mostly consists of known species whose recognition is a routine matter. It need scarcely be pointed out, however, that the recognition by a specialist of such material implies a capacity to distinguish it from the vastly greater number of related species which are not of economic importance. There is always a proportion of material which cannot be so distinguished in the present state of our knowledge, and it is the revisionary study required in this connection that constitutes the long-term aspect of the work of an identification service. An analysis of the practical purposes of an identification service may clarify the actual problems involved. There are five main purposes for which identifications are required:

(1) To recognise a pest of known importance, so that recorded experience can be used and augmented.

(2) To distinguish important pests from near relatives *in all stages*, so as to assist in surveying their incidence in endemic areas, or to recognise their spread to new areas.

(3) To designate new pests and distinguish them amongst a complex of associated insects.

(4) To aid the study of the biotic complex affecting pest populations, in connection with control by biological or insecticidal methods.

(5) To identify the natural enemies of proved pests in their endemic areas and of closely related species wherever they occur, but especially in areas to which the pest has been introduced, so as to estimate the possibility, or the extent, of successful biological control.

The first of these functions is one which should increasingly be taken over by local services, and in the case of Australia, Canada, New Zealand, South Africa and, to a less extent, India, this has already been done. Elsewhere the quality of local reference collections is very variable. Frequently they depend too much on the extent to which the Government Entomologist is taxonomically minded and the degree to which he is overworked. They should be regionally, rather than territorially organised, and in view of political developments they might best be attached to the new universities rather than to government departments or even regional research organisations. The Commonwealth Institute of Entomology will have to continue to supply authentically named examples of recognised pests for such collections for many years, but this is work which does not present special difficulties. The training of locally recruited staff for curatorships and local identification services is a matter which needs discussion.

The second purpose, of distinguishing important pests from near relatives, involves the special study of particular complexes and does not require the wide experience necessary for major revisionary work. It provides, in fact, useful training for younger workers. It essentially involves a combination of field work and the facilities provided by the large museums, where material can be studied under the guidance of an authority in the group concerned. There is very considerable scope for an expansion of work of this kind, financed by research grants for limited periods to postgraduates or to oversea university or departmental workers on a study-leave basis.

The third purpose, the designation and differentiation of new pests, arises to-day partly in the case of newly introduced crops (an increasingly rare situation) but chiefly in the case of vectors of new diseases, particularly of virus origin. It thus particularly involves the Homoptera, notably the Aphids, Cicadellids, Coccids and Aleurodids. Problems here are somewhat similar to those of (2) above, and the same approach could be made to them.

The fourth purpose, the study of the biotic complex affecting pest populations, has mainly to do with predatory and parasitic species and thus directly concerns the parasitic Hymenoptera, the Formicidae, Coccinellidae, Syrphidae, Tachinidae, Neuroptera and predatory Heteroptera, and, to an extent probably greater than at one time thought, spiders and mites. An increasing amount of work of this kind may be expected, and will certainly produce much undescribed material. Some of these groups are not well known, and the taxonomic resources available to the identification services may well prove inadequate to cope with such material.

The fifth purpose, which is really a special case of the preceding one, is to enable the recognition of the natural enemies of proved pests in their endemic areas and those of related insects wherever they occur. Because of the need to distinguish between very closely related forms and because of the complexity of the parasitic Hymenoptera, which are naturally of particular importance in this work, the field for descriptive, revisionary and " key " work is very large and the geographic range is very wide. It is in this field, as has already been pointed out, that there is an urgent need for a greater amount of pure taxonomic work. There is, however, a practical point here. Problems of identification arising from attempted biological control in temperate climates largely concern the Nearctic and Palaearctic faunas, of which adequate knowledge is available in Europe, Canada and the U.S.A. So far as the Commonwealth is concerned, and in particular the Commonwealth Institute of Entomology, it is in the parasitic fauna of the tropical and subtropical regions that the need for more taxonomic work is greatest. Close cooperation between the museum and field workers is important here, and could well be strengthened.

It is difficult to gear the resources of an identification service very closely to the practical needs outlined above. Such a service experiences in a particularly acute form the dilemma which all taxonomy faces, namely that the greater the number of identifications it is asked to make, the less time there is for the fundamental taxonomic work which alone makes fully accurate determinations possible. Consequently any kind of increase in staff is to be welcomed. An identification service, however, cannot hope to do more than make relatively small contributions to the total call for fundamental taxonomy. Although the members of the Institute staff all undertake revisionary work in their respective fields, their primary function is routine identification and for the main revisionary work we must continue to look to the museums and universities.

B. MEMORANDUM ON THE GALL MIDGES LIVING ON THE SORGHUMS, THE *PANICUM* MILLETS AND RICE

By H. F. Barnes
Rothamsted Experimental Station

The sorghum midge has recently been discovered in several territories of both East and West Africa and three preliminary investigations, in Uganda, in Nigeria and in the Gold Coast, have revealed the presence of other injurious gall midges on *Sorghum*, *Panicum*, and *Pennisetum*. The rice stem gall midge has also been discovered in Africa. The purpose of this memorandum is to focus attention on these and other gall midges of the sorghums, the *Panicum* millets and rice. With this object in view, the memorandum is divided into:

Paragraphs
A. Summary of the published information 1–11
  (i) Gall midges on the sorghums 1–6
  (ii) Gall midges on the *Panicum* millets 7–10
  (iii) Gall midges on rice 11

B. Summary of the unpublished information 12–22
  (i) Appearance of the rice stem gall midge in Africa 13
  (ii) Gall midges on the *Panicum* millets 14–18
  (iii) Gall midges on the sorghums 19–22

C. Summary of the present situation regarding the gall midges of tropical cereals in Africa 23–27

D. Suggestions and facilities for research 28–32
  (i) Appointment of a research entomologist 28
  (ii) Facilities for training 29
  (iii) Preliminary training 30–31
  (iv) Post-training research 32

A. Summary of the Published Information

(i) *Gall midges on the sorghums*

1. The best known of the gall midges attacking the inflorescence of sorghums is undoubtedly the sorghum midge (*Contarinia sorghicola* Coq.), originally described from the U.S.A. in 1898. It has since been reported from nearly all the sorghum-growing areas: Hawaiian Islands (1906), West Indies (1912), Australia (1928), Anglo-Egyptian Sudan (1930), Venezuela and Indonesia (1948), Nyasaland (1950), Uganda (1951), Aden Protectorate, Gambia, Gold Coast, Kenya, and Tanganyika (1952) and Nigeria (1953).

2. The sorghum midge is a pest of great importance. It has been reported that this midge is by far the most important insect enemy of the grain sorghums in the U.S.A., that yields of grain sorghum in Queensland have been appreciably reduced by it, and that a 25 per cent. loss of *feterita* grain was not uncommon in the Sudan.

3. The sorghum midge attacks all varieties of the grain sorghums and sorgos (the sweet sorghums) loosely known as *Sorghum vulgare* Pers. Alternative host plants in the U.S.A. are *Sorghum halepense* and *S. sudanense*. In Uganda, the sorghum midge has been reared on *S. verticilliflorum*. Owing to an error of identification it has also been recorded on *Eleusine* in Uganda (para. 16).

4. Recorded parasites include *Tetrastichus*, *Aprostocetus* and *Eupelmus* in the U.S.A. and the West Indies. In Uganda, *Tetrastichus* and *Aprostocetus* have been recorded (see also para. 22). Control measures have in the past, owing to the prohibitive cost of insecticides, been restricted to methods of cultural control.

5. Two other gall midges attacking the inflorescences of sorghums have been described from India. These are the *jola* ear-head midge, *Contarinia andropoginis* Felt, and *C. caudata* Felt; the former has also been recorded from Burma, where it is known as the sorghum grain midge. It has been suggested that *C. caudata* may be the sorghum midge, *C. sorghicola.*

6. The above paragraphs (1–5) refer only to the gall midges that attack the inflorescences and directly affect grain production. Five gall midges are known to damage the lower part of the stems, but they have not hitherto been reported as pests. They are *Dyodiplosis andropoginis* Felt, *D. indica* Felt, *D. monticola* Felt, *D. plumosa* Felt and *Orseoliella graminis* Felt. All were described from S. India and have not yet been found elsewhere. There is, finally, a malformation of the internodes involving the flower buds and found in Italy that has been ascribed to an unidentified gall midge.

(ii) *Gall midges on the Panicum millets*

7. The *Panicum* millets are considered here as including *Echinochloa*, *Eleusine*, *Eragrostis*, *Milium*, *Panicum*, *Paspalum*, *Pennisetum* and *Setaria*. The only midge known from *Echinochloa* is the grass crown midge, *Lasioptera echinochloa* Felt, whose larvae live in the decaying lower stems and crown in the U.S.A. An unidentified gall midge, resembling the rice stem gall midge (para. 11) has been recorded from *Eleusine* in the Indian subcontinent; *C. sorghicola* has recently been recorded erroneously as living in the inflorescence of *Eleusine* in Uganda (para. 16). Two gall midges, *Cecidomyia eragrostisae* Mani and *Contarinia eragrostidis* Felt, have been described from the inflorescences of *Eragrostis* in S. India and Java respectively; and three stem gall midges have been recorded from *Eragrostis*, namely *Neolasioptera agrostis* Felt in the U.S.A., and *Orseoliella* sp. and *Pachydiplosis* sp. in S. India. There is an unsubstantiated report of a stem gall midge living on *Milium* in Germany.

8. Four species of gall midge have been described from the inflorescences of *Panicum*, namely, *Lasioptera kanni* Felt (? S. India), *L. panici* Felt (U.S.A.), *L. paniculi* Felt (Philippines) and *Stenodiplosis panici* Plotnikov (U.S.S.R. and Jugoslavia). Of these, only the last-named has been reported as a pest. In addition, *Panicum* has been claimed as an alternative host plant of *Contarinia andropoginis* Felt and *C. caudata* Felt (see paras. 5 and 17).

9. Nine or ten species of gall midge have been recorded from the stems of *Panicum*. These include *Courteia graminis* Kieffer and Docters van Leeuwen (Java, Ceylon, S. India), *Dyodiplosis fluvialis* Felt (S. India), *D. fluitans* Felt (S. India), *L. inustorum* Felt (U.S.A.), *Orseolia cynodontis* Kieffer and Massalongo (Italy, France, Algeria, Eritrea, Senegal, etc.) and *Parallelodiplosis javanica* Felt (Java). There are also unidentified species reported from Arabia, Peru and Java. *Panicum* has also been claimed as an alternative host plant of *Dyodiplosis andropoginis* Felt (para. 6) and of the rice stem gall midge (para. 11).

10. While no gall midge has yet been recorded from the inflorescence of *Paspalum*, *Cleitodiplosis graminis* Tavares in Brazil causes the internodal spaces to be reduced, resulting in a terminal mass, and *Parallelodiplosis paspali* Felt (Java and S. India) and an undescribed *Lasioptera* sp. (S. India) have been recorded from the stems. There is also a record of the occurrence of possibly the rice stem gall midge (para. 11) on *Paspalum* in the Indian subcontinent. Three species of gall midge, *Itonida penniseti* Felt, *Cecidomyia penniseti* Felt, *Itonida seminis* Felt, have been described from ear-heads of *Pennisetum* in S. India; of these, *I. penniseti* may be a

predaceous form (see also paras. 14, 15, 17 and 18). An unidentified gall midge has been recorded attacking the stems of *Pennisetum* in S. India. Two species of gall midge have been recorded from *Setaria* ear-heads, namely, *Cecidomyia setaria* Felt in the U.S.A. and an unidentified Lasiopterariae in S. Rhodesia, but none is known from the stems of *Setaria* (see also para. 14).

(iii) *Gall midges on rice*

11. No gall midge has been recorded from the inflorescence of rice. The rice stem gall midge (*Pachydiplosis oryzae* (Wood Mason) Mani) is a well-known pest causing " silver shoot " or " onion shoot " on the stems of rice in the India subcontinent (1917), Ceylon (1934), Siam (1933), French Indo-China (1922), Java (1908), Dutch East Indies (1928), Burma (1924) and S. China (1941) (and see para. 13). Possible alternate host plants of *P. oryzae* include *Panicum*, *Paspalum*, *Ophiurus* and *Zizania*, while a closely allied species has been recorded from *Eleusine* (para. 7). Chalcid and Braconid parasites have been recorded from Siam, and Chalcidoid and Platygasterid parasites have been recorded from the Indian subcontinent.

B. Summary of the Unpublished Information

12. The following paragraphs (13–22) relate to unpublished information that I have acquired from material sent for identification from French Sudan, Madagascar and elsewhere, through the courtesy of Professor P. Vayssière, Dr. R. Paulian and the Commonwealth Institute of Entomology, respectively. Specimens of all these midges (mounted in canada balsam) are incorporated in the Barnes collection. All the identifications are tentative.

(i) *Appearance of the rice stem gall midge in Africa*

13. A midge almost certainly this species and making the same type of malformation of the central shoot has been discovered at Kayo, French Sudan, during 1947 and at Masa, A.-E. Sudan, during 1953. These are the first records of its occurrence in Africa.

(ii) *Gall midges on the Panicum millets*

(a) *Madagascar* (*R. Paulian, 1950, et seq.*)

14. On *Pennisetum*, there is a gall midge (Trifila: ?*Cecidomyia*) whose larvae live in the inflorescence. On *Setaria*, there are three gall midges (two Bifila—a species belonging to a genus near *Thurauia* and a ? *Stenodiplosis*; and one Trifila—? *Cecidomyia*) whose larvae live in the inflorescence. There are Bifila gall midges (close to *Stenodiplosis*) reared, respectively, from the inflorescence of *Aristida*, from the leaf buds of *Aristida*, the stems of *Trachypogon* and the leaf buds of an undetermined grass. A Trifila gall midge has also been reared from the inflorescence of *Sacciolepis*.

(b) *Anglo-Egyptian Sudan* (*? unpublished, W. P. L. Cameron, 1936*)

15. A gall midge that has been provisionally referred to *Itonida seminis* Felt was reared in 1936 from the ear-heads of *Pennisetum* at Tokar.

(c) *Uganda* (*Q. A. Geering, 1952*)

16. The gall midge reared from *Eleusine* (paras. 3 and 7) is not *C. sorghicola* as recorded, but a distinct species. This error was due to a hasty identification on my part.

(d) *Nigeria* (*J. R. G. Sutherland, 1953*)

17. On *Panicum maximum*, four distinct species have been reared, as well as parasites. One species is exceedingly similar to *C. sorghicola*; the second species is also a Bifila, but distinct; the third is a Trifila; and the fourth belongs to a different

tribe of the Cecidomyidae—the Lasiopterariae. On *Pennisetum pedicellatum*, two distinct species of gall midges have been reared; one of these is a species of *Lestodiplosis*, whose larvae are predatory; the other belongs to the Lasiopterariae, but is different from the species found on *Panicum maximum* (see above).

(e) *Gold Coast* (*J. Bowden, 1954*)

18. On *Pennisetum polystachyon* three distinct species of gall midges have been reared: one of these is exceedingly similar to *C. sorghicola* (but confirmation is needed, as only one specimen has been received); the second species is a Trifila; and the third belongs to the Lasiopterariae.

(iii) *Gall midges on the sorghums*

(a) *Nigeria* (*J. R. G. Sutherland, 1953*)

19. The following information is now available, as a result of the preliminary survey by J. R. G. Sutherland during 1953 of the distribution of the sorghum midge in Nigeria. The material is still being worked out. *C. sorghicola* apparently has been reared from *Sorghum arundinaceum*, several varieties of *S. caudatum*, many varieties of *S. durra*, many varieties of *S. guineense*, from *S. saccharatum* and from many varieties of *S. vulgare*, as well as from *Andropogon gayanus*. Its distribution is wide, samples producing the midge having been collected in the Western Province (Ijoko Otta, Ibadan, Iseyin, Akinmorin, Ejigbo, Ogbomosho, Ikeja, Epe, Ilugun, Ede), the Eastern Province (Yandev) and the Northern Province (Gusau, Zaria, Maiduguri). Parasitic Hymenoptera (possibly *Eupelmus popa* Girault, para. 22) have been reared from all the plants mentioned and in most of the localities in which the midge has been found to be present.

20. A second Bifila gall midge has been reared from the inflorescence of *S. arundinaceum* at Ado-Ekiti, Ilugun, Ede and Ogbomosho and from at least two varieties of *S. guineense* at Zaria, Epe and Ijoko Otta; and a third one from the inflorescence of *Andropogon gayanus*, at Yandev. The larvae of an inquiline Clinodiplosine gall midge have apparently occurred in the inflorescences of *S. saccharatum* at Zaria. A gall midge, probably belonging to the genus *Lestodiplosis*, whose larvae are almost certainly predaceous on other gall midge larvae, has been reared from the inflorescence of *S. arundinaceum* and probably *S. caudatum* and *S. guineense*.

(b) *Gold Coast* (*J. Bowden, 1954*)

21. What is apparently *C. sorghicola* has been reared from guinea corn and *Sorghum arundinaceum* in the Gold Coast.

(c) *Emergence of the sorghum midge and a parasite, collected from the Gambia, at Rothamsted Experimental Station*

22. An infested ear of guinea corn was received from the Commonwealth Institute of Entomology late in January 1953. It had been sent with specimens of *C. sorghicola* from the Gambia the previous December (R. W. H. Campbell, letter to C.I.E., 17.12.52). The ear was kept in the usual type of gall-midge emergence-cage and kept damp from January to May, 1953, and again from September, 1953, to January, 1954. One parasite, identified provisionally by G. J. Kerrich as *Eupelmus popa* Girault, emerged on 22nd April, 1953. *E. popa* is a well-known parasite of *C. sorghicola* in the U.S.A. Specimens of the sorghum midge emerged spasmodically during May, June and October, 1953 (actually 2 males and 4 females). Emergences occurred almost daily between 16th November, 1953, and 4th January, 1954 (in this period 47 males and 62 females emerged). Further spasmodic emergences took place between 12th and 25th January, 1954 (in this period 3 males and 3 females emerged). The total emergences at Rothamsted of the sorghum midge from this single ear from Gambia have been, so far, 121 (52 males and 69 females) between May1953 and January 1954.

C. Summary of the present Situation regarding Gall Midges of tropical Cereals in Africa

23. The gall midges of tropical cereals menace the schemes to increase these crops. In the case of sorghum, serious decreases in grain-production have occurred in various other parts of the world, and plant-breeders in Africa are seriously concerned with the gall midges on their variety-trial plots. In addition to *C. sorghicola*, two other gall midges have already been discovered (para. 20) in the inflorescences of sorghum in Nigeria, and a preliminary survey has shown that one of these is already a potential grain pest, since it is present in large numbers. Parasites belonging to three genera are now known to exist in Africa (paras. 4 and 22).

24. The theory that cultivated sorghums originated in the Kordofan Province of the Sudan may account for the presence of the sorghum midge (and its parasites) and other species in Africa. If this is the case, the growing of imported American varieties may be serving to increase the endemic populations of midges, owing to the consequent extension of the flowering period of sorghums. On the other hand, the sorghum midge, and perhaps the other species, can easily be transported from country to country (paras. 1 and 22), and the native gall-midge populations may therefore have received, and may still be receiving, invigorating new strains from abroad. A search for endemic host plants of the sorghum midge in Uganda has shown that it is breeding on *S. verticilliflorum*. It is also known (para. 3) to breed in the U.S.A. on two other species native to Africa, *S. sudanense* and *S. halepense*, but up to the present it does not appear to have been discovered on these plants in Africa.

25. As regards the *Panicum* millets, the presence has been revealed of another gall midge species on *Eleusine* (para. 16) in Uganda. In Nigeria, a preliminary survey of the inflorescences of *Panicum* and *Pennisetum* has similarly revealed the presence of potential gall midge pests (para. 17). One of those on *Panicum* may be the sorghum midge, but the evidence for this needs confirmation and it may be a distinct species. In the Gold Coast, also, several potential gall-midge pests of *Pennisetum* have been discovered (para. 18). One of these may be the sorghum midge, but this needs confirmation. There is an inflorescence gall midge present in the Sudan on *Pennisetum* (para. 15).

26. The literature indicates that several other species of gall midge that are potential pests of the grain have been described from sorghums and other millets in other parts of the world. Some of these or other additional species may be in Africa or be brought there. In addition, a considerable number of gall midges that attack the stems of sorghums and other millets has been described throughout the world and similarly may become pests if transported to new areas. The transport of such stem feeders does not, however, seem to be quite so probable as that of the inflorescence feeders, although the world-wide distribution of the Hessian fly indicates that the possibility must not be overlooked. Some of these or other species may be in Africa or be accidentally introduced.

27. The appearance in Africa of what is almost certainly the rice stem gall midge of the east (para. 13) must also give rise to concern in view of the attempts to expand rice-growing in Africa.

D. Suggestions and Facilities for Research

(i) *Appointment of a research entomologist*

28. The situation warrants the immediate appointment of an entomologist to be trained to work full time on the gall-midge problem of tropical cereal crops. There is a need for surveys to be made in order to discover and assess the prevalence of injurious gall midges on cereal crops in Africa; this will result in a considerable amount of purely systematic work. The surveys should be followed by biological studies, including investigations into host-plant range and varietal resistance, so that control measures can be devised.

(ii) *Facilities for training*

29. The Barnes collection of gall midges is rich in the gall midges of tropical cereals. In addition to series of the sorghum midge, *C. sorghicola*, from almost every part of the world in which it has been recorded, the collection contains all of the recently discovered gall midges and in the case of some of the species, long series. Furthermore, it has been demonstrated that the sorghum midge can easily emerge at Rothamsted from infested ears gathered overseas (para. 22), and Dr. H. H. Mann, Director of the Woburn Experimental Station, is experimenting with the growing of sorghums in this country.

(iii) *Preliminary training*

30. My duties as a member of the staff of the Entomology Department at Rothamsted, although they have allowed me to become the hub of research and information on gall midges of economic importance throughout the world, preclude me from devoting all my time to the systematic and biological work that should be done on the gall midges of tropical cereals; but I could assist in identifying material and training an appointee.

31. Before proceeding to Africa, the appointee could thus be trained at Rothamsted, where he could familiarise himself with the range of gall midges he would be likely to encounter in the field. He could also assist in investigating the possibilities of carrying out biological studies on these midges in this country and thus become trained in biological techniques. He could also get acquainted with the sorghums and other tropical cereals and grasses at Kew and elsewhere.

(iv) *Post-training research*

32. The officer appointed would then go overseas to carry out surveys and assessments of prevalence, and this should be followed by home study of the material amassed. The investigations would then develop on the lines suggested in para. 28.

APPENDIX VI

REVIEWS OF WORK IN ECONOMIC ENTOMOLOGY IN THE COMMONWEALTH, 1948-54*

CONTENTS

	PAGE
Australia	162
British Guiana	186
Canada	
Division of Entomology	188
Division of Forest Biology	206
Cyprus	225
East Africa	
East African Agricultural and Forestry Research Organisation	227
Fiji	228
Gold Coast	
Department of Agriculture	233
West African Cacao Research Institute	240
Department of Tsetse Control	243
Jamaica	244
Kenya	248
Malaya	258
Mauritius	281
New Zealand	285
Nigeria	290
Northern Ireland	304
Northern Rhodesia	306
Pakistan	310
Scotland	319
Southern Rhodesia	324
Tanganyika	330
Trinidad	
Department of Agriculture	336
Imperial College of Tropical Agriculture	337
Uganda	339
West Africa	
West African Institute for Trypanosomiasis Research	341
Zanzibar	344

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* In accordance with Resolution 33 of the Fifth Commonwealth Entomological Conference, a request was circulated in October, 1953,to the appropriate authority in each of the Commonwealth countries for a review of work in economic entomology covering the years 1948–54, for presentation to the Sixth Conference. It was proposed that, if the Conference approved, these reviews should be published as part of its Report. This approval was given (see Resolution 24, p. 12).

The reviews are published in the form in which they were received. They have in most cases been prepared by the chief entomologist of the government department that deals with agriculture in the country concerned; in certain cases where that department is also responsible for work in veterinary or medical entomology, references to those fields will be found.

AUSTRALIA

REVIEW OF ENTOMOLOGICAL RESEARCH, 1948–1954

PAGE
Introduction 162
Agricultural Pests 164
Insects of Pastures and Field Crops 164
Horticultural Pests 165
Insects of Stored Products 168
Insects of Forests and Forest Products 169
Insects of Medical Importance 170
Insects of Veterinary Importance 171
Household Insect Pests 172
Biological Control 174
Insecticides—including Formulation and Methods of Application .. 174
Insects and Viruses 175
Insect Physiology 176
Population Dynamics 177
Taxonomy 178
Quarantine 179
Papua, New Guinea—Agricultural and Horticultural Pests 180

INTRODUCTION

During recent years there has been a growing conviction in Australia that research on the physiology and ecology of insects and factors influencing their populations should receive increasing attention. The advent of many new insecticides has naturally led to extensive testing against pest species, but many problems have also arisen owing to the widespread use of DDT and other insecticides. For example, the use of DDT against certain horticultural pests has led to a marked increase in the damage caused by others, due mainly to the destruction of their natural enemies. The discovery of a strain of the cattle tick (*Boophilus microplus*) resistant to BHC and the suspicion that the tick is also becoming resistant to DDT in certain areas have been partly responsible for a complete revision of the research programme on this pest, and more attention is being given to ecological aspects of the problem.

Entomologists in the State Departments of Agriculture are responsible for the bulk of the applied research, extension services, and some of the fundamental research in Australia. There has been an increase in the amount of work being done at the universities in most States, and some very useful experimental, ecological and taxonomic work has been published since 1948. The Division of Entomology of the Commonwealth Scientific and Industrial Research Organisation in Canberra is the largest unit engaged in fundamental research. Here there are strong units working on insect physiology, biological control, virus vectors and insect pathology. Work on population dynamics has recently been extended to include field studies as well as experiments in the laboratory. Smaller units are engaged in ecological studies on certain specific pests or groups of pests, their work generally being complementary to that of State entomologists who are more concerned with direct control measures. As a corollary mainly to the ecological work and biological control, there has been a marked increase, more by necessity than design, in the amount of taxonomic work carried out by officers of the Division of Entomology. The volume of such work which needs to be done is so great that the museums and universities, whose responsibility it has previously been considered, have been unable to cope with it.

The review which follows, which is set out under broad general headings, is necessarily condensed for publication and deals only with the most important aspects of entomological research in Australia. It has been compiled from reports, some of them very comprehensive and detailed, furnished principally by the following institutions:

Commonwealth Scientific & Industrial Research Organisation

Division of Entomology, Canberra, A.C.T.
Division of Forest Products, Melbourne, Victoria
McMaster Animal Health Laboratory, Sydney, N.S.W.
Veterinary Parasitology Laboratory, Brisbane, Queensland

Museums

The Australian Museum, Sydney, N.S.W.
The South Australian Museum, Adelaide, South Australia

State Departments

Agriculture

Agricultural Section, Northern Territory Administration, Northern Territory
Biology Branch, Department of Agriculture, Victoria
Department of Agriculture, Western Australia
Department of Agriculture & Stock, Queensland
Department of Agriculture, Stock & Fisheries, New Guinea
Entomology Branch, Department of Agriculture, New South Wales
Entomology Branch, Department of Agriculture, Tasmania

Forestry

Department of Forests, Territory of Papua and New Guinea
Division of Wood Technology, Forestry Commission of New South Wales

Other Institutions

Department of Territories, Canberra, A.C.T.
Department of Health (Quarantine Branch), Canberra, A.C.T.
Queensland Institute of Medical Research, Brisbane, Queensland

Universities

Department of Zoology, University of Melbourne, Victoria
Department of Entomology, University of Queensland
Department of Zoology, University of Sydney, New South Wales
Department of Zoology, University of Western Australia, Perth, Western Australia
Department of Entomology, Waite Agricultural Research Institute, University of Adelaide, South Australia
School of Public Health & Tropical Medicine, University of Sydney, New South Wales
The New England University, Armidale, New South Wales

Delegates from other countries who may wish to obtain further information will find most Australian work in print in the journals published by the Departments of Agriculture and museums in the various States, and in the Australian Journal of Zoology; the Australian Journal of Biological Sciences; the Australian Journal of Agricultural Research; the Journal of the Australian Institute of Agricultural Science; and the Australian Journal of Experimental Biology and Medical Science. Some of the more specialised work, such as in the field of biochemistry, is commonly published in overseas journals.

A notable contribution to Australian economic entomology has been the compilation of a list of common names of insects and allied forms occurring in Australia. Agreement has been reached in common names of roughly 650 species and the list will shortly be published. An extract from this list forms the index to this report.

AGRICULTURAL PESTS

Heliothis armigera

This pest continues to prove troublesome, particularly in linseed crops in Queensland, where recommended treatment is DDT emulsion at the rate of 1 lb. of active insecticide per acre, 15 gallons of spray providing adequate cover if applied shortly after the moths become active following flowering. Boom spraying is the most effective and widely used method of application. DDT sprays and dusts have given effective protection to tomato crops.

Agrotis infusa

This species, attacking wheat and related crops in Queensland, has been effectively controlled by DDT at the rate of ½ lb. p, p′ isomer per acre applied by boom spray.

Plusia spp.

Certain species may be serious pests of tobacco in Queensland and are not successfully controlled by DDT, although dieldrin has given satisfactory control. Health hazards and possibilities of tainting have complicated control of certain tobacco pests, but experiments with newer insecticides have shown promise of a satisfactory pest control schedule.

Gnorimoschema operculella

Improved methods of control in Queensland have been concentrated on proper integration of DDT spraying of the growing crop and hilling to ensure the maximum production of sound tubers, while DDT treatment of tubers has proved effective in preventing attack during storage.

Aphis craccivora

Work on this aphid by the Zoology Department, University of Sydney, has been concentrated on two main lines of study—investigation of swarming and migration and factors responsible for resistance to attack of certain varieties of beans. Other investigations have been on the bionomics of *Anomalaphis comperei.*

Thrips tabaci

Where this species has proved a minor factor in the production of onions and onion seed in Queensland, DDT at the rate of ½ lb. p, p′ isomer per acre has given effective control.

INSECTS OF PASTURES AND FIELD CROPS

Insect pests of Australian pastures may be broadly divided into those that attack, mainly or solely, the higher-value, largely improved pastures of the moister coastal and subcoastal regions, and those whose damage is mainly to natural pastures of lower carrying-capacity in the drier inland regions. In the first group the most important are: The Coleoptera, *Aphodius howitti* and *Heteronychus sanctae-helenae;* the Lepidoptera, *Oncopera* spp. and *Talis* sp.; the orthopteron, *Acheta commodus;* the collembolan, *Smynthurus viridis;* and the mite, *Halotydeus destructor.* The second group includes the Orthoptera, *Chortoicetes terminifera, Austroicetes cruciata,* and *Gastrimargus musicus;* and the lepidopteron, *Agrotis infusa.*

In all cases, investigations have been concentrated on the field ecology and on control by the newer insecticides. The life-cycle and ecology of *Aphodius* has been studied comprehensively over the whole of its range and the climatic and management factors influencing its abundance determined. Control may be obtained by the application of 1 lb./acre of DDT as a dust or absorbed in superphosphate, or more cheaply by lindane at only 4 oz./acre. Both insecticides have a marked persistence in the soil. *Heteronychus* has been regarded primarily as a pest of crops, but it also damages coastal dairy pastures. Its control in this habitat is now under investigation. For small-scale treatment, DDT, chlordane, BHC, and dieldrin have all given partial control.

Life-cycle and ecological studies of *Oncopera* spp. are in progress in South Australia and Tasmania, supported by laboratory work, particularly on the eggs. Abundance is influenced to an important degree by management practices, especially the progressive use of improved pastures, and by the moisture supply. Control may be obtained by low-volume DDT sprays or by DDT-impregnated superphosphate. Investigations of the webworm, *Talis* sp., have elucidated the life-history and demonstrated the possibility of effective control with DDT dusts or sprays.

Acheta commodus, a rather local pest on black clay flats, has been studied in the field in South Australia. Control may be obtained with BHC-bran baits; use of lindane and dieldrin incorporated in superphosphate is being tested. *Smynthurus* and *Halotydeus* commonly occur together on improved pastures in the winter rainfall region, especially of Western Australia. In several respects they present similar ecological and control problems. The abundance of the former is markedly influenced by predatory Bdellid mites of the genus *Biscirus*, but there are also interactions between *Smynthurus* and *Halotydeus*. Fundamental ecological work on the whole complex of species is in progress. Control of *Smynthurus* may be obtained with parathion, which has little effect on the Bdellids, while *Halotydeus* is very sensitive to DDT.

Investigations on *Chortoicetes* have been concerned chiefly, on the ecological side, with the testing of measures likely to reduce the favourability of its outbreak areas to multiplication and swarm-formation. Phase studies have also been carried out, yielding results similar to those obtained with other locusts. In control campaigns the emphasis is shifting from BHC-bran baits to BHC-water sprays at 3 oz. gamma isomer per acre, and various spraying machines, especially of the air-blast and boom-spray types, are coming into favour. Treatment from aircraft, both of flying and settled swarms, is employed in addition to ground treatment, BHC in diesel fuel oil being the insecticide chiefly used. Tests of sprays employing the newer insecticides have been made also on *Austroicetes cruciata* in Western Australia. Dieldrin at 2 oz. per acre was particularly effective. Life-cycle, ecological, and phase investigations have been carried out on *Gastrimargus* in Central Queensland. These have enabled suggestions to be made as to the location of its outbreak areas.

Agrotis infusa, a pest of winter herbage on the eastern fringe of the western plains of New South Wales, has been investigated with respect to the seasonal migrations of the adult and its gregarious aestivation in caves on the tops of mountains.

Horticultural Pests

Strumeta tryoni

In 1947, *Strumeta tryoni* was found firmly established in suburban areas of Adelaide and an eradication campaign, following the broad procedures of the 1928–29 campaign in Florida, was recommended and undertaken.

The campaign provided for maintenance of host-free areas of one mile radius surrounding any known foci of infestation by stripping all fruit, supplementary bait sprays within treated areas and “ blanket ” spraying with DDT of hedges and inaccessible vegetation where necessary. Baited traps were maintained for sampling and movement of fruit from infested areas was prohibited.

Areas in which it was first recognised were treated in 1947 and 1948 and no recurrence has been recognised since. In another closely settled urban area it has proved remarkably persistent, small foci recurring in 1947, 1950, 1952 and 1953.

Altogether, 30 square miles have been treated and no evidence of the fly has been found for one whole summer. The cost of the eradication campaign (for *S. tryoni* and *C. capitata*), including labour and compensation, now approaches £1,000,000. The campaign so far has prevented the infestation of commercial fruit growing areas, at the same time enabling householders to continue fruit production.

Following the introduction of *S. tryoni* into Victoria and with eradication as an ultimate objective a laboratory was established at Bairnsdale in 1949, as a centre for studying the extent of infestation in eastern Victoria, the importance and distribution of wild host fruits and the life-history of the fly under field and laboratory conditions.

Investigations in Queensland on *S. tryoni* and other fruit-flies have resulted in the clarification of the host relationship and pest status of many species and indicated that pineapples and strawberries have never been recorded as fruit-fly hosts.

Work in New South Wales with tartar emetic, tartar emetic-parathion or parathion-sugar bait and DDT or DDT-parathion cover sprays has given promising results. Tests with ethylene dibromide fumigation of fruit have shown that 1 lb. per 1,000 cubic feet is the dosage required to ensure fruit free from *S. tryoni*, this being double the dosage recommended by Hawaiian workers for the control of *Dacus dorsalis*.

Other work on the general biology of *S. tryoni* and *S. cacuminata* with special reference to laboratory breeding technique, mating behaviour, influence of light on fecundity, host relationships, development of physiological races and the influence of light on the rhythms of adult emergence is being carried out in the Zoology Department, University of Sydney.

Entomological work in the Northern Territory on fruit-flies has been mainly concerned with a survey of all possible native and commercial hosts and the distribution of the widespread *Afrodacus jarvisi*.

Ceratitis capitata

In Western Australia, the only State in which this fly now appears to be of permanent economic significance, benzene hexachloride, parathion, hexone, dieldrin, aldrin and chlordane have been tested as bait sprays and proved quite effective but not superior to the standard sodium fluosilicate. Tests with lure traps to investigate natural spread failed to demonstrate any tendency for the fly to spread more than a few hundred yards from a focus of infestation.

In 1948 an intense infestation by *Ceratitis capitata* was discovered in a different suburban area of Adelaide from that affected by *S. tryoni* the year before. The same eradication measures have been employed. *C. capitata* was in evidence in 1948, 1949 and 1950 and 20 square miles of suburban gardens were stripped of fruit and sprayed. It has not been reported since 1950.

In Victoria the fly was found to occur in 1953 in suburban areas near Melbourne and in a commercial fruit growing area near Longwood. Prompt action was taken for its eradication along similar lines to those used in South Australia.

Cydia pomonella

In Queensland, New South Wales, Victoria, South Australia and Tasmania considerable reduction in moth infestation has resulted from the use of DDT, although problems in controlling Tetranychid mites and *Eriosoma lanigerum* have been accentuated. Tests in Victoria have shown that parathion is useful for controlling the mites. In Western Australia, where codling moth is not considered to be permanently established, it is believed that 14 separate outbreaks within the last 50 years have been eradicated successfully.

Eradication measures consist of quarantining affected orchards, establishment of buffer zones, restriction of fruit movement, an intensive spraying schedule carried out by Government teams and the continual inspection of fruit and tree bandages. No evidence of codling moth has been detected in the State during the 1953–54 season.

Cydia molesta

The incidence of this pest has increased considerably in New South Wales metropolitan orchards and in 1953 a widespread outbreak occurred in the Murrumbidgee Irrigation Area. In New South Wales metropolitan orchards, DDT sprays for fruit fly control do not appear to produce any pronounced reduction in fruit injury. This moth, until recently, has been responsible for serious losses in fruit growing areas in the Goulburn Valley, Victoria, but three or four sprays with 0·1 per cent. DDT have been found to give consistently good control.

The first outbreak of the moth in Western Australia was recorded from the Darling Range in 1952. An eradication campaign was immediately instituted. The known area of infestation is considered to have been greatly reduced and no escapes were located outside the quarantine zone. No moth activity has been detected during the 1953–54 season.

Ceroplastes destructor

In Queensland, tests on the addition of new detergents to sprays have given more effective control of this scale. In New South Wales, white oil sprays in mid-December followed by white oil-soda sprays have given effective control. Sodium metasilicate proved effective but at higher concentrations than soda ash, while E.605 is reported to have reduced the efficiency of soda in laboratory trials.

Aonidiella aurantii

Control of this scale is a matter of concern in inland and coastal citrus areas, particularly New South Wales, Victoria and central Queensland, though cyanide fumigation and white oil sprays give effective control.

It continues to be the most important pest of citrus in Victoria.

Recommendations at present prescribe oil sprays followed by fumigation; oil spray followed by parathion for heavy infestations or two parathion sprays of not less than 0·04 per cent. active insecticide where fumigation is not available.

Parathion has been tested in New South Wales, but local efficiency of this insecticide falls short of consistently optimistic overseas reports. Zinc bordeaux-mixture spray prior to cyanide fumigation has been found to prevent risk of tree injury.

Typhlocyba froggatti

In Western Australia this recently introduced pest has proved troublesome in apple-growing districts. Satisfactory control has been achieved by application of a single correctly timed spray of 0·1 per cent. DDT or two treatments with nicotine sulphate-white oil. Further investigation of this pest has also been carried out in Tasmania.

Tarsonemus pallidus

This mite was first found in Tasmania in February 1952. It was the first record of the mite in Australia, and a survey in March 1953 showed it to be then widespread. Control experiments with parathion, Pestox and Systox are in progress but as yet no positive results have been obtained.

Bryobia praetiosa

Field tests in Victoria with new acaricides have shown that Dimite, Ovotran and Sulphenone are at least as good as parathion for the control of summer infestations of this mite, while Systox and P.C.P.B.S., which were not included in earlier field trials, have given promising results in small ' pilot ' experiments. New acaricides are also being tested in other States.

Aleuroplatus citri

This newly introduced pest, so far only recorded from Western Australia, has proved troublesome in the Darling Range and coastal citrus areas. The life-history has been investigated and tests show that nicotine sulphate-white oil, DDT and parathion give effective control.

Acheta commodus

BHC-bran baits have given good results in Victoria against heavy infestations of adult crickets, but results have been less satisfactory where feed is plentiful and the crickets immature.

Tests are being carried out incorporating various insecticides, including lindane and dieldrin, with superphosphate for application during normal top-dressing practices.

Miscellaneous Horticultural Pests

Other horticultural pests on which investigations have been continued by State Departments of Agriculture include *Tortrix postvittana*, *Eurytoma fellis*, *Scirtothrips signipennis*, *Aonidiella citrina*, *Cosmopolites sordidus*, *Amblypelta nitida*, *Leptops squalidus*, *Phaulacridium vittatum*, *Camplyomma livida*, *Thrips imaginis*, *Pantomorus godmani*, *Perperus vermiculatus*, *Rhoecocoris sulciventris*, *Pseudococcus* spp., *Phylloxera vitifoliae*, *Anuraphis persicae-niger*, *Myzus cerasi*, *Myzus persicae*, *Tetranychus telarius* and *Paratetranychus pilosus*. Much of the work with these pests has been on development of more effective control measures by the use of newer insecticides. In some cases (*e.g.*, *Tortrix postvittana*) satisfactory biological control has been interfered with by the use of DDT against other pests.

Heterodera marioni

In Queensland higher yields of good quality vegetables have proved the value of DD fumigation against eelworms.

INSECTS OF STORED PRODUCTS

Wheat occupies a very important place in the economy of the country. The crop is stored in orthodox permanent silos and in temporary bulk and bagged stores. Constant troubles are experienced from insect pests and these are dealt with by fumigation, using carbon bisulphide, methyl bromide or mixtures of hydrocarbons. Pyrethrum-based grain protectants have been tested on a laboratory scale but have not been used in the field. A new terminal silo to be built in Queensland is to be fitted with gas circulation plant. As long as present storage methods are employed there is little hope of any marked reduction in the numbers of insect pests as really effective control measures are difficult to put into practice. Alternative systems have therefore been reviewed, particular attention being paid to storage methods designed with insect control in mind. Air tight storage has been selected as the most practical method that can be employed as, if successful, its extensive use would enable the crop to be kept in an insect and rodent-free condition without the need for periodic treatment with fumigants or insecticides. The main research effort has therefore been an investigation of the underlying principles involved. The reduction in the oxygen content of the intergranular air, due to the respiration of the insects and the grain, has been shown to be the important factor. The increasing concentrations of carbon dioxide play only a very secondary part in the control of the insects. It is hoped that full scale trials of air tight grain storage will be possible.

Following its use in New Zealand dichloroethyl-ether has been successfully used to control cheese mites in holding rooms and cheese stores. BHC and DDT have been officially recommended for the treatment of some cereal seeds and their use now complies with State Seed Acts. Some experimental work has been carried out on the control of stored product pests with radio frequency electric fields. Successful tests have been given to a centrifugal percussion steriliser.

In the Territory of New Guinea losses in imported native foods are particularly high, while damage to European foods are less but constantly occurring. Only poor storage facilities exist. BHC dusts have proved effective against Bruchidae. *Ephestia* has responded to the use of BHC wettable powders. In the Territory and on the Australian mainland much infestation occurs after foodstuffs have left the manufacturers. Some attention has therefore been paid to the development of insect-proof packing materials.

Insects of Forests and Forest Products

In Australia entomological research associated with forests and forest products is carried out mainly by the Divisions of Entomology and Forest Products of C.S.I.R.O., the Division of Wood Technology of the New South Wales Forestry Commission, and the Forest Products Laboratory of the Queensland Forest Service. The bulk of such research is concerned with termites as they constitute the most important destructive agencies in this field.

The assessment of the termite resistance of assorted materials is made by both laboratory and field tests. Standard laboratory colonies of *Nasutitermes exitiosus*, *Coptotermes lacteus* and *C. acinaciformis* give a rapid and accurate measure of the relative resistance of such things as commercial timbers, plastics, cable sheathings, wall boards, plywoods and preservative treatments. Such tests are used as a screening for field tests which determine the permanence of preservative treatments etc. under service conditions. Field tests in progress now include many thousands of preservative treated specimens, among which are those belonging to the International Termite Exposure Test.

Modifications of the field testing technique now enable satisfactory assessments of the resistance of wall boards to be made, and the efficiency and permanence of soil poisons and repellents to be determined. Materials so tested as potential soil treatments include various arsenicals, creosote, pentachlorophenol, DDT, and chlordane.

Many hundreds of series of termites from all over the continent are added to the Australian collection each year, thereby increasing the knowledge of the distribution of the various species. Such collections also include new material, descriptions of which are published at appropriate times.

The widespread occurrence of, and damage caused by, *Lyctus brunneus* has resulted in considerable investigation of the biology and control of this species. Biological studies have dealt with oviposition, speed of development, longevity and larval nutrition. The control investigations have concentrated on practical methods of immunising veneer and sawn timber against attack. Borax and boric acid have been found very effective and satisfactory schedules have been evolved for the treatment of sawn timber. Veneer is now proofed by momentary dipping in a treating solution followed by 2–4 hours' block stacking to allow diffusion of the treating solution. This simple and effective treatment has gained wide acceptance in the industry. Plywoods can also be proofed for at least eight years by adding BHC to the glue line, but because of the success of momentary dipping this latter method has not been developed commercially.

Although *Anobium* is not an important problem at present, the rapid development of exotic plantations, together with the importation of large quantities of susceptible timber species has focussed attention on this insect. Some attention has been given to the development of rearing techniques that would be capable of supplying requisite experimental material.

A considerable advance in the treatment of *Anobium* and *Lyctus* infestations has been the discovery that β, β' dichloroethyl ether is very toxic to all stages of both species and penetrates at least 1 inch of timber with ease.

The interception of *Sirex* in imported timber cargoes and its subsequent establishment in Tasmania has resulted in the development of heating schedules and fumigation techniques and schedules to eradicate infestation in timber entering mainland ports. Considerable success has been achieved by fumigating with methyl bromide under plastic sheets.

Pin hole borers are occasionally troublesome in rain-forest timbers if logging is delayed. Satisfactory protection of logs *in situ* can now be given cheaply and effectively by creosote coatings applied to susceptible log surfaces.

Investigation of a severe attack by the Buprestid, *Diadoxus erythrurus*, on cypress pine, *Callitris glauca*, indicated that this was associated with weakening of the trees by fire. Subsequent diminution of the infestation was shown to be due to the activities of Hymenopterous parasites.

In recent years a new problem has arisen in the occurrence, in plague numbers, of two Phasmids, *Podacanthus wilkinsoni*, and *Didymuria violescens*. The former is the more important species; although it has a wide range it occurs in pest numbers in only restricted areas. Nevertheless, it has caused severe defoliation of many thousands of acres of forest and constitutes a potential menace to important commercial species of eucalypts. An intensive study is being made of the biology of these Phasmids, and of the possibilities of biological and/or direct control by mechanical or chemical methods.

Insects of Medical Importance

The war-time stimulus to research, reported in 1948, ended with the war. Primary malaria disappeared from Australia, and remained a major problem only in New Guinea and adjacent territories. Filariasis vanished from Brisbane, though continuing at a low level in more northern cities. Dengue disappeared, and had not returned to the end of 1953.* With the reduction of the population at risk and the use of Chloramphenical in treatment, the importance of scrub typhus decreased considerably. Nevertheless, work on Arthropods of medical interest continued at a higher level than before the war, partly, as after the 1914–18 war, because of continued interest, and partly as a result of fresh stimuli—Murray Valley encephalitis in human populations and myxomatosis in rabbits—which focussed attention on groups that had previously been relatively neglected.

Blattidae

The discovery of natural infections with *Salmonella* in two species of cockroaches (*Periplaneta americana* and *Nauphoeta cinerea*) led to experimental demonstration that several species could be infected with several types of *Salmonella* and remain carriers for several weeks, which in turn led to studies of the life-histories, longevity and behaviour of several native and introduced species.

Culicidae

The Administration in New Guinea has established a Malaria Control Unit and Training School, where the war-time studies of the local Anophelines and their control are being continued and expanded. Additional information has been obtained about the distribution of Anophelines in the Torres Strait Islands. On the mainland it has been found that *Anopheles annulipes* is particularly associated with rabbits (and probably other small ground mammals), and that it is not a good host for the Murray Valley encephalitis virus, confirming earlier views that its public health importance is small.

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* A new outbreak began in Townsville in 1954.

Work on Culicines has been more active. Systematics and life-histories of Queensland species have been studied; field behaviour and resting places of southern species have been extensively investigated by the myxomatosis workers; the *pipiens* complex in Victoria has been elucidated; the genetics of the *scutellaris* group have been examined; and precipitin tests have been used in an extensive study of the feeding habits of many Australian species. The widespread occurrence of Murray Valley encephalitis virus in 1951 led to tests of some 18,000 mosquitoes from the Murray Valley and 33,000 from the neighbourhood of Townsville for the presence of virus in 1952. All were negative, but other evidence suggests that the virus may have disappeared from the country by then. It has been shown experimentally that this virus will multiply and persist in several Australian species of Culicine mosquitoes.

Other Blood-Sucking Diptera

The Ceratopogonidae, Simuliidae, and the genus *Phlebotomus* have been revised. When a current revision of the Tabanidae is completed, the Australasian species of blood-sucking Diptera should be reasonably well known, while the studies of the myxomatosis workers will have contributed substantially to an understanding of their biology.

Ticks and Mites

Ixodes holocyclus naturally infected with *Rickettsia* (*Coxiella*) *burneti* has been reported.

A complete monographic review of the Trombiculid mites has been published and is serving as a foundation for further field and systematic studies in this group in Queensland.

INSECTS OF VETERINARY IMPORTANCE

Sheep Blowfly

The status of the two species of *Lucilia* attacking sheep in Australia has been critically examined. *L. cuprina* is outstandingly important, *L. sericata* of very minor importance, and the species are quite distinct.

Insectary studies indicated that 1 per cent. DDT or 0·5 per cent. BHC afforded marked protection to sheep against body strike by *Lucilia cuprina* for several weeks at least. This was confirmed by field tests, which also indicated that good results were obtained by concentrations of BHC as low as 0·05 per cent. Further work proved that jetting gives better protection against establishment of larvae than spraying, and that BHC, dieldrin and aldrin give more lasting protection than DDT.

The rate of dissemination and maturation of newly emerged sheep blowflies has been investigated and population density measurements have been made of several species of veterinary importance occurring in traps. Laboratory and field studies of the breeding of the bush fly, *Musca sorbens*, a serious pest of stock, have also been made.

Lice

Studies have been made on the bionomics of the sheep lice, *Damalinia ovis*, *Linognathus pedalis* and *L. ovillus*. Control of sheep lice and ked (*Melophagus ovinus*) was shown to be effected by a single dipping in DDT or BHC.

Fog-producing machines have been found of limited value for the control of ectoparasites of sheep.

Cattle Tick

Research on the cattle tick, *Boophilus microplus*, has shown that a colloidal DDT preparation and a BHC dispersible paste are suitable for use in dips against this species, including an arsenic-resistant strain which had developed. Much chemical work has been done in investigating aspects of the use of toxicants in dips. Chromatographic methods showed a differential decomposition of gamma BHC, the biologically inert isomers remaining more or less unaffected. This accounts for a loss of biological efficiency observed in BHC dipping fluids. Studies have been made of the penetration of DDT into adult cattle ticks. A technique has been developed for the chemical determination of residual insecticides on cattle hair. Laboratory methods are in use for the screening of potential acaricides and have also demonstrated the existence of a highly BHC-resistant strain of cattle tick in Queensland, and an arsenic-resistant strain in New South Wales. Spraying trials of the effects of such toxicants as chlordane, toxaphene, dieldrin and aldrin have shown promising results.

Studies of the non-parasitic stages of the cattle tick have shown how the species overwinters in southern Queensland. Females which fall after early April seldom reproduce, but females which fall in late March and early April give rise to progeny which produce adults falling in August. These August-maturing ticks are the parents of the spring generation. Preventing the fall of adult females by strategically timed dipping for some months after the winter depression in population precludes the development of the heavy pasture infestations usual in summer. Rotational grazing trials for tick control are also in progress.

The sensory physiology and habits of the larval cattle ticks have also been investigated, and methods developed for measuring larval population densities in pastures. Studies were made to relate cattle movements and grazing habits to the distribution of cattle tick larvae within a paddock.

Mites

The mite, *Zygoribatula longiporosa*, has been shown to be the intermediate host of the tapeworm *Moniezia benedeni* infesting cattle in Queensland.

A common, mange-like condition of horses known as Queensland Itch has been found to be associated with the development of hypersensitivity to the bites of a sandfly, *Culicoides robertsi*, and regular weekly treatment with DDT prevented development of the condition.

HOUSEHOLD INSECT PESTS

Argentine Ant

The Argentine ant (*Iridomyrmex humilis*) infests extensive areas of city and residential areas in Australia. The estimated areas infested are : Western Australia—40 square miles; Victoria—8 square miles; New South Wales—3 square miles.

Experiments by C.S.I.R.O. in co-operation with State Departments of Agriculture in New South Wales and Western Australia have shown that the Argentine ant can be eradicated from infested areas at a relatively low cost by the use of chlordane or dieldrin sprays. The spray is applied by trained labour to all situtations favoured by the ants for nests or trails, plus a complementary treatment of spraying a strip of spray, 4 inches to 6 inches wide, on a grid pattern of not more than 10 feet square to all lawns and open situations. It is not necessary to spray inside buildings.

Ants infest more than 60 separate areas in the three square miles in Sydney; eradication was begun with 2 per cent. chlordane in December 1952, but in the light of more recent experiments, chlordane has been replaced with 0·75 per cent. dieldrin at no greater cost.

Experiments in Western Australia have shown that 2 per cent. dieldrin is completely effective for more than two and a half years after application and 1 per cent. dieldrin for more than one year. Eradication is possible with 0·5 per cent. dieldrin and experiments are in progress to study its effectiveness at still lower concentrations.

House-fly

Earlier experimental work on kerosene-based household space sprays led to recommendations regarding the minimum concentrations of pyrethrins and DDT necessary to effect satisfactory knockdown and kill of flies and certain other household insects. These recommendations formed the basis on which most of the sprays manufactured during the last six years have been formulated. Methoxychlor and piperonyl butoxide have recently been imported for use in household, dairy and warehouse sprays and low-pressure aerosols.

Residual insecticide treatment has been used for fly control both indoors and out of doors on an unorganised private basis but not in intensive community compaigns. Prevention of fly-breeding in sewage beds has been studied in Western Australia. Laboratory tests showed that BHC at 12 p.p.m. and dieldrin at 2 p.p.m. in culture medium are toxic to larvae and prevent breeding. Both insecticides have been used effectively in the sewage beds. Comparatively few cases of the development of insecticide-resistance have been reported, although the occurrence of wild flies up to 30 times as resistant to DDT as a susceptible laboratory strain was demonstrated by laboratory tests in 1950.

Adult house-flies of an insecticide-susceptible laboratory strain have been one of the principal test insects employed in quantitative toxicological investigations. Methods for administering insecticide solutions to individual flies by topical application in doses proportional to body weight have been evolved, and the degree of precision obtained has made possible a detailed investigation of factors which influence :

(*a*) the susceptibility of flies to standardised insecticide treatment, and

(*b*) the toxicity of insecticides to standard flies.

Factors examined include sex and age of flies, age of parents, and period of pre-adult development.

A study of the inheritance or DDT-resistance in an American strain of house-flies was carried out at the Department of Zoology, University of Western Australia.

Silverfish

Investigations on the control of *Ctenolepisma longicaudata* have shown that this species is introduced into houses principally in firewood. It can be kept under control by frequent thorough spraying of rooms and cupboards with pyrethrum space sprays. However, it was demonstrated that lasting control could be effected by the use of 10 per cent. DDT dust blown into crevices behind picture rails, skirtings, architraves, cupboards, etc., and applied to the upper surface of the ceiling. An average-sized house requires 2 lb. of dust for treatment in this manner.

Cockroaches

The principal economic species are *Blattella germanica* and *Periplaneta americana.* Investigations in Canberra led to the use of 10 per cent. DDT dust for the control of the former species in houses, service kitchens, etc. It is applied in a similar manner to that for silverfish control, but special attention is given to hiding places near stoves, boilers, hot-water pipes, and under sinks. Deodorised BHC and chlordane are now being recommended. Chlordane applied as a 2 per cent. emulsion or kerosene solution to small areas surrounding hiding places appears to be the most efficient control measure to date.

BIOLOGICAL CONTROL

The principal institutions concerned with biological control research in Australia are the C.S.I.R.O. Division of Entomology, the State Departments of Agriculture, the Waite Agricultural Research Institute, and the Queensland Department of Lands. In recent years, most introductions of natural enemies of pests have been made by C.S.I.R.O. which provides material for liberation throughout the Commonwealth by maintaining cultures of each species for some years. In securing initial cultures of the required insects, use is often made of the services provided by the Commonwealth Institute of Biological Control.

The problems that have received attention in the post-war period are the following :

INSECT PESTS : *Gnorimoschema operculella*, *Plutella maculipennis*, *Pieris rapae*, *Nezara viridula smaragdula*, *Strumeta tryoni*, *Aonidiella aurantii* and several others (such as *Ceroplastes destructor*, *C. rubens*, *Listroderes obliquus*), for which preliminary work has begun aiming at parasite introductions in the next few years. All these insects are major pests in one or more States of the Commonwealth, and are regarded as suitable subjects for control by entomological means.

WEED PESTS : *Hypericum perforatum*, *Eupatorium adenophorum*, *Heliotropium europaeum* and *Lantana camara*.

A good many of the insects introduced in recent years have been established, and others have at least been recovered in the field, with the possibility existing of their subsequent permanent establishment.

Five parasites have been introduced against the cabbage moth (*Plutella*), at least four of which are established, and a high degree of parasitism of this host is probably general in Australia. Against the cabbage white butterfly (*Pieris*), three parasites have been introduced and established and the field parasitism of this species approaches 100 per cent. in summer time. Introductions against the potato moth (*Gnorimoschema*) have apparently been less satisfactory : although four parasites of this pest were introduced, only one is definitely known to be established. Recently, introductions have been made of both egg and adult parasites of the green vegetable bug (*Nezara*) (four parasite species), but, though a few recoveries have been made, the importance of the introductions cannot yet be assessed. Another insect established is *Comperiella bifasciata*, a parasite of the red scale (*Aonidiella*).

Work on the biological control of weeds has been less extensive. With St. John's Wort (*Hypericum*), field studies have been made of the effect of introduced Chrysomelid beetles upon it, and recently another natural enemy of the weed, a gall-fly, has been introduced. Against the Crofton-weed (*Eupatorium*), a Tephritid gall-fly has been introduced from Hawaii and established in Australia. A survey of the insect enemies of the Common Heliotrope (*Heliotropium*) has been made in Europe, this field study indicating that insects suitable for introduction into Australia do not exist. Finally, an Australian entomologist is participating in the Central American search, organised by Hawaii, for natural enemies of *Lantana*.

INSECTICIDES—INCLUDING FORMULATION AND METHODS OF APPLICATION

In the period under review, changes in Australian insect control practices, which are best described as revolutionary, have taken place. Very few of the control measures previously recommended now remain, the great majority having been superseded by the use of one or other of the chlorinated hydrocarbon and organic phosphorus insecticides developed during the last decade. These new materials are now controlling many pest species at a lower population level than has hitherto been possible. Some outstanding examples of effective and economical control over species for which no satisfactory measures previously existed are : the buffalo fly by DDT, the sheep blowfly by DDT and BHC, the sugar-cane grubs by BHC, and several species of pasture pests by DDT and BHC.

These advances are largely the result of laboratory and field research by State and Commonwealth entomologists whose combined reports indicate, at this stage, that control measures, at least reasonably satisfactory, now exist for most of the important insect pests. However, control measures are constantly being reviewed as new materials and methods become available. DDT continues to be the most widely used of the newer insecticides. BHC, HETP and parathion have been in general use for some years. The effectiveness of chlordane and dieldrin against the Argentine ant has made the eradication of this species from certain areas a distinct possibility. Aldrin and toxaphene have been used extensively for locust control. Dieldrin shows promise in several fields (locusts, black beetle, sheep blowfly). The systemics and the modern acaricides have been tested.

Some of these insecticides, particularly DDT and BHC, have now been used extensively for several years, but there is substantiated evidence of only one species having increased in resistance, namely the cattle tick, although a few reports of resistant houseflies have been noted.

Advances have also been made in machinery and methods for large-scale crop protection. Power dusting machines gave way to aircraft for the treatment of linseed crops attacked by *Heliothis armigera*, and dust was superseded by spray concentrate. Aircraft, low-volume boom sprayers, air-blast machines and fog machines have all been used against *Chortoicetes terminifera*. A detailed study of insecticide application by aircraft has been carried out in Victoria. Orchard power sprayers have not been radically changed, although fixed booms, elevated spray platforms and increased pressure and output allow of practically automatic spraying.

In the control of ectoparasites of sheep there is a tendency towards the use of spray dips and fogging machines, but laboratory investigations have shown that fogs do not penetrate the fleece, and that the insecticide deposited on the surface is rapidly lost. Spraying also gave longer protection than fogging against blowfly strike in insectary trials. Field tests have confirmed that spraying is more effective than fogging.

INSECTS AND VIRUSES

Animal Viruses

Myxomatosis

The phenomenal spread of this disease of rabbits over vast areas of Australia in 1950–52 was due mainly to the activity of insects, probably mainly mosquitoes. Laboratory studies have shown that the disease is carried mechanically on the mouthparts and that ticks, mites, lice and biting flies can all act as vectors. Mosquitoes and other biting flies carrying the virus have been recovered from the field on a number of occasions.

Murray Valley Encephalitis

This virus has been shown to be transmitted by several Culicine and Aëdine mosquitoes, but not by the one Anopheline tested. Attempts to recover the virus from 50,000 mosquitoes collected in the Murray Valley and Queensland failed, although several other viruses, not yet characterised, were isolated.

Q Fever

The Rickettsia causing Q Fever has been isolated from wild-caught *Ixodes holocyclus*, demonstrating that yet another tick can act as a vector of this disease.

Polyhedrosis

A contribution to the rapidly expanding field of viruses attacking insects was made by the description of a polyhedral virus that, during 1952 and 1953, caused about 1 per cent. mortality in larvae of an Anthelid pasture caterpillar, *Pterolocera amplicornis*.

Plant Viruses

Two new plant viruses have been described in the period under review.

Carrot Motley Dwarf was transmitted by *Cavariella aegopodii* but not by several other carrot Aphids. The disease has been a limiting factor in the production of carrot seed in some years. The problem can be greatly reduced by the use of resistant varieties.

Rugose Leaf Curl Virus is a newly discovered pathogen that was first isolated from field-caught Agalliine leafhoppers. The virus is very unusual in being transmitted through the egg of its vector, *Austroagallia torrida*.

The leafhopper, *Orosius argentatus*, was previously known as a vector of the virus of tobacco yellow dwarf. More recently it has also been incriminated as a vector, though an inefficient one, of tomato big bud and lucerne witches' broom. It has also been suggested that it transmits potato purple top wilt, which is thought to be caused by the same virus causing tomato big bud.

Further work on the vectors of tomato spotted wilt attacking potatoes has incriminated *Thrips tabaci* as the vector in the Canberra district, and the rôle of *Myzus persicae* and *Macrosiphum euphorbiae* (=*gei*) in the spread of potato leaf roll has also been studied. Work is in progress on the vectors of citrus quick decline in Australia.

Mechanisms of Transmission of Viruses by Insects

A programme of work has been undertaken in which the mechanisms by which insects transmit viruses is being studied. Reports have been published on aspects of the physiology relating to virus transmission of leafhoppers, Aphids and mosquitoes. The mechanism of transmission of potato leaf roll virus is under examination at the moment.

INSECT PHYSIOLOGY

Cuticle

The cuticular lipoids of several insects, notably from scales of the genus *Ceroplastes*, have been analysed and examined for physical properties. Cuticular proteins have been isolated and examined and a study is in progress dealing with their precursors, involving a study of blood amino acids prior to and during cuticular formation. The mechanism of tanning of the proteins and the chemical reactions involved have been studied. The chemistry and metabolism of chitin is being studied and also the possibility of chitin-protein complexes being present in the cuticle.

Blood

The substances responsible for the green colour of insect blood have been examined.

Digestion

A considerable amount of work has been carried out on the digestion of keratin by clothes moth larvae, carpet beetle larvae and chewing lice. This has involved a study of the proteolytic enzymes and the pH and oxidation reduction potential of the digestive juices, the histology, histochemistry and tracheation of the digestive tract, sulphur metabolism, metal detoxification, composition of food and excreta and such enzyme systems as cysteine desulphydrase and xanthine oxidase.

The occurrence of mucoid substances in insects has been studied and also the pH of the digestive juices in Lepidoptera.

Work has been carried out on the occurrence, composition, fine structure and rate of production of the peritrophic membrane.

A histochemical study of functional differentiation between groups of cells in the midgut of blowfly larvae has been carried out.

Excretion

This has been studied in larvae of the blowfly, clothes moth and carpet beetle. A study is also in progress on uric acid metabolism in insects. The honey dew of scale insects has been examined.

Insect Flight

The enzymes responsible for energy liberation in insect muscle have been studied and the role of mitochondria in these processes examined.

Nutrition

The influence of larval and adult nutrition on reproduction in the sheep blowfly has been studied.

Regeneration

Work is in progress on the interaction between regeneration and the moulting cycle in the cockroach.

Diapause

A study of the factors influencing the onset and termination of diapause has been made in a number of insects and mites.

Behaviour

Work has been carried out on the sensory physiology of the cattle tick. In the fruit fly the following have been studied : mating behaviour, response to humidity, influence of light on fecundity and on emergence rhythm and host preference. A study has been made of the response of mosquito larvae to light.

POPULATION DYNAMICS

Since 1948 work in this field has developed along these lines :

Theoretical Investigation

The major work carried out is based on well-established general knowledge about populations and on implications which follow directly from it. The results indicate that insect populations are " self-governing ". Insect populations regulate their numbers in relation to their own properties and those of their environments. This they do by depleting and impairing essential things to the threshold of favourableness. The mechanism of density governance is usually intraspecific competition either amongst insects for a critically important requisite or amongst natural enemies for which the insects themselves are requisites. The reaction of governing factors induced by density change holds populations in a state of balance in their environments.

Another study suggests that the mathematical theory of interspecific competition attributed to Lotka and Volterra is unsound.

Laboratory Experimentation

Numerous large-scale population experiments with the Australian sheep blowfly, *Lucilia cuprina*, have provided much evidence in support of the conclusions reached by the major theoretical studies mentioned above.

Other experimental work, using the grain beetles, *Rhizopertha dominica* and two distinct strains of *Calandra oryzae*, has centred on the idea of the innate (or intrinsic) rate of increase of an insect species as a parameter of basic importance in population studies. Observations have been made on the influence of factors such as temperature, moisture and kind of food on the innate capacity for increase.

Using flour beetles, *Tribolium* spp., an experimental analysis has been made of the effects of interspecific and intraspecific competition on fecundity.

Field Observations

Several major field investigations have yielded useful information on population fluctuations and dynamics, *e.g.* the study of Chrysomelid beetles introduced into Australia for the control of the weed, *Hypericum perforatum*, and the analysis of fluctuations in the abundance of *Thrips imaginis* in relation to weather and other factors. Recently, a start was made on long-term field investigations on selected Psyllid and Coccid species, aimed specifically at determining the factors responsible for population regulations in such insects.

TAXONOMY

It is a truism that taxonomy is basic to the biological sciences, in the sense that without taxonomic knowledge all other knowledge of animals and plants is largely unusable. In the older countries taxonomy reached an advanced stage of development during the period when most zoologists were occupied with taxonomic and comparative morphological study. On the other hand, in " young " countries, taxonomic knowledge of the local faunas is for the most part still meagre, and its extension is handicapped by the fact that taxonomy is no longer fashionable, even if still respectable.

In Australia, pioneer work by overseas taxonomists, based on material accumulated by expeditions, was followed by local work on a number of groups by men such as Waterhouse, Froggatt, Tillyard, Turner, Blackburn, etc. From about 1920 there was a decline in taxonomic investigation, and it seems to have been tacitly assumed by Australian entomologists that a reasonably satisfactory knowledge of most of the insect groups had been attained. How erroneous this belief was has been demonstrated in spectacular fashion by the results of the sudden upsurge in taxonomic activity that has occurred during and since the last war. The increased interest should be ascribed to the progressive revelation of the true extent of our taxonomic ignorance of the insect fauna resulting from the wartime concern with disease-carrying insects and the intensive ecological studies on many groups being conducted particularly by the Division of Entomology of C.S.I.R.O.

The new taxonomic work has been taken up very largely, though not exclusively, by C.S.I.R.O. It has demonstrated that, except in a few groups such as the butterflies, probably well under 50 per cent. of the Australian insects are named. In such circumstances synecological studies become virtually impossible.

When we consider that Australia is as large as the United States, that its population is less than one-fifteenth of that of the United States and its scientific resources infinitely less, that it is younger by almost 150 years, and that its fauna contains a very large percentage of endemics, the task of bringing taxonomic knowledge to a stage of development commensurate with the demands already being made upon it is a truly appalling one. Student training in insect taxonomy is given at several Australian universities and can be supplemented by post-graduate training overseas, but the main difficulty is the shortage of positions for taxonomists and of opportunities for entomologists engaged in other work to practise taxonomy as a major side-line. As has been said, marked improvement has taken place in recent years, but the position is till far from satisfactory.

Since 1948, Australian workers have published taxonomic papers on the Culicidae and Ceratopogonidae, the Trypetidae (Dacinae), *Lucilia*, Acarina (*Aponomma* and *Amblyomma*), Formicidae, Isoptera, Lepidoptera, Nemestrinidae, Apioceridae, Mydaidae, Simuliidae, Tabanidae, Psychodidae and other groups. Many taxonomic papers on Australian insects were published also by overseas workers.

Taxonomic work by overseas specialists is at present in progress on the Acridoidea, Braconidae and Ichneumonidae, and cetain groups in the Diptera. Australian taxonomists are working on a number of groups including Isoptera, Acridoidea, Blattoidea, Coccidae (Aspidiotini), Psyllidae, Cleptidae, Proctotrupidae, Ampulicidae, Cynipoidea, Chalcidoidea, Formicidae, Apidae, Scarabaeidae (Dynastinae), Culicidae, Ceratopogonidae, Simuliidae, Tabanidae, Trypetidae, Calliphoridae, Asilidae and many other Dipterous families, and certain groups in the Lepidoptera (principally Noctuidae and Microlepidoptera).

Taxonomy of Australian ticks and lice is carried out by the Division of Animal Health and Production of the C.S.I.R.O., and of the biting Ceratopogonidae likely to be related to animal disease transmission, by the School of Public Health and Tropical Medicine at the University of Sydney. The taxonomy and biology of pest Simuliidae and Tabanidae are studied at the Queensland Institute of Medical Research.

QUARANTINE

The policy has been vigorously pursued of endeavouring to keep Australia free from the many serious insect pests not yet established or widespread in this continent by the enforcement of regulations under the Quarantine Act and by associated strict inspection of all plant material upon its arrival in Australia.

This policy is proving its worth and, in the period under review, very few insect pests have gained access to Australia.

Quarantine problems have increased in complexity in recent years for the following reasons :

(1) Importations of plant material from almost all parts of the world have increased materially in volume.

(2) Our vigorous immigration policy has been associated with the importation of many non-commercial parcels of plant material which migrants desire to bring in as personal luggage.

(3) Australia has rapidly developed air transport and therefore has lost isolation so valuable to quarantine.

The following notes on some interceptions during the past five years will illustrate the wide range of host material, countries of origin and insects identified. Many are intercepted while in the larval stage and destroyed without identification.

(1) Siricid wood wasps have repeatedly been found in timber, in packing cases and in prefabricated houses originating in Europe and in timber from New Zealand, necessitating heat treatment or fumigation of shiploads of material. The principal species found were *Urocerus gigas*, *Sirex juvencus* and *Sirex noctilio*. One small plantation of *Pinus radiata* near Hobart, Tasmania is infected with *Sirex noctilio* but the rest of the pine plantations comprising some 280,000 acres are still free of *Sirex*.

(2) Narcissus flies, both the larger (*Merodon equestris*) and the lesser (*Eumerus* spp.), have been found in bulbs, principally Narcissus, from Europe. Difficulties in detection by inspection and subsequent treatment have resulted in regulations requiring that bulbs subject to Narcissus fly attack must be treated under supervision in the country of origin before export to Australia.

(3) Ants in various media. The Singapore ant (*Monomorium destructor*) in orchids and labels; Pharaoh's ant (*M. pharaonis*) in orchids from New Guinea. *Anoplolepis longipes* in nursery stock from Sourabaya. Argentine ant (*Iridomyrmex humilis*) in railway sleepers from West Indies and in insulating cork from Spain or Madeira; *Oecophylla smaragdina* in nursery stock from Japan.

(4) European Red Mite (*Paratetranychus pilosus*) in nursery stock from England and from Holland was found on a number of host plants.

(5) Scales of various species on Citrus fruits, on nursery stock, on ivy and on orchids were frequently intercepted—mainly from European sources.

(6) Many Bostrychid and Scolytid timber borers in logs and timber imported from Borneo, Malaya, Brunei, New Guinea.

(7) European corn borer (*Pyrausta nubilalis*) on millet from Europe.

(8) Strawberry mite (*Tarsonemus pallidus*) on strawberries from England.

(9) Many cosmopolitan insects like bean and pea weevils (*Bruchus* spp.), grain weevils (*Calandra* spp.), cockroaches, clothes moths, *Anobium* and *Lyctus* furniture beetles were intercepted on numerous occasions. The material is always treated before release, or destroyed if infection is heavy.

(10) European house borer (*Hylotrupes bajalus*) has been identified in Queensland from prefabricated houses imported from Europe. It is hoped to eradicate it before it becomes established.

PAPUA and NEW GUINEA

Agricultural and Horticultural Pests

At present the main export crops of Territory agriculture are coconuts, rubber and cacao. Rubber is singularly free from insect pests and most entomological work in the period under review has dealt with coconut and cacao pests. Of the two crops, coconut is by far the more important currently, but cacao, a crop relatively new to the Territory, is being expanded rapidly under the influence of extremely high post-war prices.

Other crops of lesser current importance include rice, kenaf, manila, hemp, cotton, peanuts, green manure and cover crops.

Agricultural Pests

Oryctes rhinoceros

This important pest of coconuts is now well established on the Gazelle Peninsula, New Britain, and to a lesser extent in parts of New Ireland. Damage is caused by the adults to the crown of the palm and, when extensive, palms may be killed directly by beetle attack or by entry of secondary organisms. Control of the larvae by biological means has proved a difficult matter as no specific parasites are recorded from larvae of *O. rhinoceros*. Attempts have been made to improve control by the introduction of two species of Scoliid parasites of related species of *Oryctes*, *Scolia ruficornis* having been introduced from Zanzibar and *S. oryctophaga* from Mauritius. Both parasites were liberated in New Britain towards the end of 1952, and a further liberation of *S. oryctophaga* was made in mid 1953.

As it is considered that complementary action by parasites and predators will be necessary to bring about any appreciable reduction in the numbers of the pest, introductions of the predatory Histerid, *Platylister chinensis*, have been made from Fiji, while a second predatory Histerid, *Leionota* sp., and a predatory Elaterid, *Pyrophorus* sp., have been introduced from Trinidad. Observations have also been made on local species of Dynastids and parasites associated with them. Investigations on chemical control of *O. rhinoceros* have been mainly concerned with treatment of compost pits with persistent insecticides against the larvae, good results having been obtained with 6·5 per cent. γ isomer BHC (Gammexane) at a dosage of 2 oz. per 10 cubic feet. Hand dusting with 3 oz. of $2\frac{1}{2}$ per cent. DDT powder has given good protection to young palms during early stages of growth and helps to prevent delay in young palms coming into bearing when not protected from attack.

Sexava nubila, Sexava nova-guineae

Some six species of Tettigoniids probably cause severe defoliation and loss of yield in coconuts in the Bismarck Archipelago, but the more important species are *Sexava nubila* and *S. nova-guineae*. The possibilities of controlling these insects by aerial spraying have been investigated but do not appear practicable under Territory conditions, while power dusting or spraying from ground level has proved difficult owing to irregularities of terrain, isolated nature of many affected plantations and difficulties in obtaining suitable machinery which will work effectively under tropical conditions. Soil treatment against emerging hoppers and treatment of basal portions of palm trunks against ovipositing females have shown some promise of improved control.

Work with the Encyrtid parasite, *Leefmansia bicolor*, has been continued and on several occasions since the war outbreaks of *Sexava* have been brought under control in parts of New Britain and New Ireland by mass liberations of the wasps. Attempts have also been made to introduce the Strepsipteron, *Stichotrema dallatorreanum* from the New Guinea mainland and establish it on *S. nubila* in New Britain, but work on the project has been hampered since this parasite is known only from the female, which appears to require fertilisation. The matter of determining the host relationship of the hypothetical male of the parasite is likely to be extremely difficult.

Promecotheca papuana

Ordinarily a minor pest, this beetle is kept under control by its indigenous parasites, but where normal overlapping of generations is prevented by *Pyemotes ventricosus*, the parasites are prevented from functioning effectively. In the Rabaul district the introduction of the parasite, *Pleurotropis parvulus*, has reduced the pest to an insignificant level, but in other localities sporadic outbreaks have resulted in considerable losses. Laboratory stocks of *P. parvulus* are being maintained to deal with such outbreaks.

Other pests of coconuts responsible for localised damage on which investigations have been made include *Brontispa longissima*, *Axiagastus campbelli*, *Rhincophorus* spp., *Tirathaba rufivena*, *Parasa lepida* and several other species of minor importance.

Pantorhytes plutus

This weevil borer attacks cacao in the Bismarck Archipelago, while related species are associated with cacao on the New Guinea mainland. The bionomics of *P. plutus* and the longicorn borer, *Glenea aluensis*, also a pest of cacao, have been studied. Investigations of a Dryinid parasite of both borers suggest that there is little hope of it being used effectively against them. Some control has been achieved by hand-picking during the early wet season population peak, while tree banding experiments using Ostico mixed with 10 per cent. DDT have given some promise of more effective control.

Parabryocoropsis typicus, *P. cheesmanae*, *P. duni*, *Pseudodoniella pacifica*

These Capsids comprise a group only recorded from cacao in New Guinea as recently as 1950, their action being similar to that of West African cacao Capsids. More recently another Capsid, *Helopeltis clavifer*, has been found attacking cacao fruit in Papua. Studies of the bionomics of the principal species, *P. typicus*, have proved difficult, as both males and females seldom live long in captivity. To date, field trials on the control of the Capsids have been of limited extent, but good control has been obtained by dusting with 1·3 per cent. γ isomer BHC. Indications are that two dustings at four-weekly intervals, prior to the onset of the wet season, will give reasonably good control at relatively low cost. DDT does not appear to be as effective as BHC and the Gold Coast practice of using concentrated DDT paint on trees is not satisfactory owing to different growth habits of the types of cacao grown in Papua and New Guinea.

Other miscellaneous pests of cacao which have received attention include *Batocera nebulosa*, *Dihammus* sp., *Monohammus* sp., *Zeuzera coffeae*, *Neotermes papua*, *Pansepta teleturga*, *Salina celebensis*, *Exophthalmida glauca*, *Platyachus ruralis*, *Rhyparida* spp., *Monolepta semiviolacea*, *Microlepta* sp., *Ectropis bhurmitra*, *Achaea janata* and *Prodenia litura*.

Some work has also been carried out on the other pests of agricultural crops as yet little cultivated in the Territory, being mainly concerned with the economic species associated with the crops referred to earlier.

Horticultural Pests

Investigations on horticultural crops have been largely restricted to determining the pest species involved, as well as trials with such standard insecticides as DDT, BHC, toxaphene, aldrin and dieldrin for the protection of vegetable crops in wide use. The principal species to which attention has been given include *Melanagromyza phaseoli*, *Pyrausta damoalis*, *Prodenia litura*, *Spodoptera mauritia* and *Heliothis armigera*.

Achatina fulica hamillei

Studies of the life-history, ecology and methods for control of the Giant African Snail have been continued. Some difference of opinion exists as to the true economic status of this snail, but it is probably more a horticultural than an agricultural pest, causing considerable losses in native food gardens and European vegetable and flower gardens. There is a distinct possibility that it could become of some agricultural importance to such crops as peanuts, caster oil and kenaf if produced on a sufficiently large scale. Main centres of infestation are still the Kavieng and Rabaul districts, Bismarck Archipelago and the Hansa Bay district of New Guinea. Despite lack of adequate quarantine facilities, the snail has not greatly increased its spread to other areas in the post-war years. Life-history observations have been carried out over a period of 2½ years and ecological observations have been made on feeding habits, duration of aestivation, resistance to desiccation and rate of spread.

Earlier attempts to obtain stocks of predators from East Africa proved unsuccessful due to dry conditions during the visit of an investigator engaged on another project, but further attempts are being made to obtain stocks of two species for experiments on an isolated snail-infested island. Chemical control investigations have been mainly concerned with the attractiveness of metaldehyde, the lethal quality of calcium arsenate and the use of creosote or coal tar as repellents. A 3 per cent. dispersion of metaldehyde in relatively old sawdust has been shown to be both attractive and lethal as well as being much less expensive than proprietary preparations. This preparation has proved of value in protecting susceptible plants such as young cacao during the first two to three months. Sprays and washes containing metaldehyde and calcium arsenate proved less effective. Apart from calcium arsenate, trials with standard insecticides have produced negative results. The repellent value of crude creosote and DNOC applied to planks edging small gardens has been studied. Some observations have also been carried out on the resistance or otherwise of certain vegetables and flowers to snail attack, tobacco showing a marked non-susceptibility.

INDEX

Scientific Name	Common Name	Page
Achaea janata L.		181
Achatina fulica hamillei Bowditch	giant African snail	182
Acheta commodus (Walk.)	field cricket	164, 165, 168
Afrodacus jarvisi (Tryon)	Jarvis' fruit fly	166
Agrotis infusa (Boisd.)	Bogong moth	164, 165
Aleuroplatus citri Takahashi	citrus whitefly	168
Amblypelta nitida Stål	fruit spotting bug	168
Anobium punctatum (Deg.)	furniture beetle	169, 170, 180
Anomalaphis comperei Pergande		164
Anopheles annulipes Walk.	common Australian anopheline	170
Anoplolepis longipes Jerd.		179
Anuraphis persicae-niger (Smith)	black peach aphid	168
Aonidiella aurantii (Mask.)	red scale	167, 174
Aonidiella citrina (Coq.)	yellow scale	168
Aphis craccivora Koch	cowpea aphid	164
Aphodius howitti Hope	pasture cockchafer	164, 165
Austroagallia torrida Evans		176
Austroicetes cruciata (Sauss.)	small plague grasshopper	164, 165
Axiagastus campbelli Dist.		181

Scientific Name	Common Name	Page
Batocera nebulosa Bates		181
Biscirus lapidarius (Kram.)	bdellid mite	165
Blattella germanica (L.)	German cockroach	173
Boophilus microplus (Can.)	cattle tick	162, 172
Brontispa longissima Sharp		181
Bryobia praetiosa Koch	bryobia mite	168
Calandra oryzae (L.)	rice weevil	177
Calandra spp.	grain weevils	180
Campylomma livida Reut.		168
Cavariella aegopodii (Scop.)	carrot aphid	176
Ceratitis capitata (Wied.)	Mediterranean fruit fly	166
Ceroplastes destructor Newst.	white wax scale	167, 174
Ceroplastes rubens Mask.	pink wax scale	174
Ceroplastes spp.	wax scales	176
Chortoicetes terminifera (Walk.)	Australian plague locust	164, 165, 175
Comperiella bifasciata How.	red scale parasite	174
Coptotermes acinaciformis (Frogg.)		169
Coptotermes lacteus (Frogg.)		169
Cosmopolites sordidus Germ.	banana weevil borer	168
Ctenolepisma longicaudata Esch.	silverfish	173
Culex pipiens (complex)		171
Culicoides robertsi		172
Cydia molesta (Busck)	oriental fruit moth	167
Cydia pomonella (L.)	codling moth	166
Dacus dorsalis Hendel	oriental fruit fly	166
Damalinia ovis (L.)	sheep body louse	171
Diadoxus erythrurus (White)	small cypress jewel beetle	170
Didymuria violescens (Leach)		170
Dihammus sp.		181
Ectropis bhurmitra		181
Ephestia sp.		169
Eriosoma lanigerum (Hansm.)	woolly aphid	166
Eumerus spp.	lesser bulb flies	179
Eupatorium adenophorum Spreng.	crofton-weed	174
Eurytoma fellis (Gir.)	citrus gall wasp	168
Exophthalmida glauca		181
Gastrimargus musicus (F.)	yellow-winged locust	164, 165
Glenea aluensis Gah.	cacao longicorn	181
Gnorimoschema operculella (Zell.)	potato moth	164, 174
Halotydeus destructor (Tuck.)	red-legged earth mite	164, 165
Heliothis armigera (Hübn.)	northern budworm	164, 175, 182
Heliotropium europaeum L.	common heliotrope	174
Helopeltis clavifer Walk.		181
Heterodera marioni		168
Heteronychus sanctae-helenae Blanch.	black beetle	164, 165
Hylotrupes bajalus (L.)	European house borer	180
Hypericum perforatum L.	St. John's wort	174, 178
Iridomyrmex humilis (Mayr.)	Argentine ant	172, 179
Ixodes holocyclus Neum.	paralysis tick (scrub tick)	171, 175
Lantana camara L.	lantana	174
Leefmansia bicolor Waterst.		181
Leionota sp.		180
Leptops squalidus (Boh.)	fruit tree root weevil	168
Linognathus ovillus (Neum.)	sheep face louse	171
Linognathus pedalis (Osb.)	sheep foot louse	171
Listroderes obliquus Gylh.	vegetable weevil	174
Lucilia cuprina (Wied.)	Australian sheep blowfly	171, 177
Lucilia sericata (Meig.)	European green blowfly	171
Lyctus brunneus (Steph.)	powder post beetle	169, 170, 180
Macrosiphum euphorbiae (Thomas)	potato aphid	176
Melanagromyza phaseoli (Coq.)	bean fly	182

Scientific Name	Common Name	Page
Melophagus ovinus (L.)	sheep ked	171
Merodon equestris F.	larger bulb fly	179
Microlepta sp.		181
Moniezia benedeni	cattle tapeworm	172
Monohammus sp.		181
Monolepta semiviolacea		181
Monomorium destructor (Jerd.)	Singapore ant	179
Monomorium pharaonis (L.)	Pharaoh's ant	179
Musca domestica L.	house-fly	173
Musca sorbens Wied.	bush fly	171
Myzus cerasi (F.)	cherry aphid	168
Myzus persicae (Sulz.)	green peach aphid	168, 176
Nasutitermes exitiosis (Hill)		169
Nauphoeta cinerea (Oliv.)	speckled cockroach	170
Neotermes papua (Desn.)	cacao termite	181
Nezara viridula smaragdula (F.)	green vegetable bug	174
Oecophylla smaragdina F.	green tree ant	179
Oncopera spp.	underground grass grubs	164, 165
Orosius argentatus (Evans)	brown jassid	176
Oryctes rhinoceros L.	rhinoceros beetle	180
Pansepta teleturga Meyr.		181
Pantomorus godmani (Crotch)	Fuller's rose weevil	168
Pantorhytes plutus Obert.	cacao weevil borer	181
Parabryocoropsis cheesmanae Ch. & Car.	cacao capsid	181
Parabryocoropsis duni Ch. & Car.	cacao capsid	181
Parabryocoropsis typicus Ch. & Car.	cacao capsid	181
Parasa lepida Cram.		181
Paratetranychus pilosus (C. & F.)	European red mite	168, 179
Periplaneta americana (L.)	American cockroach	170, 173
Perperus vermiculatus Lea		168
Phaulacridium vittatum (Sjöst.)	wingless grasshopper	168
Phlebotomus spp.	moth flies	171
Phylloxera vitifoliae (Fitch)	grape phylloxera	168
Pieris rapae (L.)	cabbage white butterfly	174
Platyachus ruralis Fst.		181
Platylister chinensis		180
Pleurotropis parvulus Ferr.		181
Plusia spp.	looper caterpillars	164
Plutella maculipennis (Curt.)	cabbage moth	174
Podacanthus wilkinsoni Macl.	ringbarker phasmid	170
Prodenia litura (F.)	tobacco cluster-grub	182
Promecotheca papuana (Cski.)	coconut leafminer	181
Pseudococcus spp.	mealy bugs	168
Pseudodoniella pacifica Ch. & Car.	cacao capsid	181
Pterolocera amplicornis Walk.		175
Pyemotes ventricosus (Newp.)	hay itch mite	181
Pyrausta damoalis		182
Pyrausta nubilalis (Hübn.)	European corn borer	180
Pyrophorus sp.		180
Rhincophorus sp.		181
Rhizopertha dominica (F.)	lesser grain borer	177
Rhoecocoris sulciventris (Stål)	bronze orange bug	168
Rhyparida spp.		181
Rickettsia (*Coxiella*) *burneti*		171
Salina celebensis		181
Scirtothrips signipennis Bagn.	banana rust thrips	168
Scolia oryctophaga Coq.		180
Scolia ruficornis F.		180
Sexava nova-guineae	coconut grasshopper	180
Sexava nubila Stål	coconut grasshopper	180, 181
Sirex juvencus L.	wood wasp	179
Sirex noctilio F.	wood wasp	179
Sirex spp.	wood wasps	170
Smynthurus viridis (L.)	lucerne flea	164, 165

Scientific Name	Common Name	Page
Spodoptera mauritia (Boisd.)	armyworm	182
Stichotrema dallatorreanum Hof.		181
Strumeta cacuminata (Her.)	solanum fruit fly	166
Strumeta tryoni (Frogg.)	Queensland fruit fly	165, 166, 174
Talis spp.	webworms	164, 165
Tarsonemus pallidus Banks	strawberry mite	167, 180
Tetranychus telarius L.	red spider	168
Thrips imaginis Bagn.	plague thrips	168, 178
Thrips tabaci Lind.	onion thrips	164, 176
Tirathaba rufivena Meyr.		181
Tortrix postvittana (Walk.)	light-brown apple moth	168
Tribolium spp.	flour beetles	177
Typhlocyba froggatti Baker	apple leafhopper (canary fly)	167
Urocerus gigas L.	wood wasp	179
Zeuzera coffeae Nietn.		181
Zygoribatula longiporosa		172

BRITISH GUIANA

REVIEW OF ECONOMIC ENTOMOLOGY FOR THE YEARS 1948–1954

PESTS OF SUGAR-CANE

Froghopper (*Aeneolamia flavilatera*)

This pest is now controlled satisfactorily by the application of a locally constituted BHC/limestone dust (approximately 0·4 per cent. BHC) at the rate of approximately 400 lb. per acre. The dust remains effective for some three months after application, and application is usually made by hand distribution.

Sugar-cane Borers (*Castnia licoides*, *Diatraea saccharalis*, *Diatraea canella*)

Temporary flooding, hand collection, were the methods of controlling *Castnia*. *Diatraea saccharalis* is still being effectively controlled by the Amazon Fly (*Metagonistylum minense*). *Diatraea canella* tends to be on the increase and about 90 per cent. of borer damage is caused by this species.

Scarabeid Beetle Larvae

The three species (*Dyscinetus geminatus*, *D. bidentatus* and *Ligyrus ebenus*) which damage cane roots in sporadic outbreaks are now controlled by temporary flooding and spraying with BHC formulations.

PESTS OF RICE

Borers

It seems clear that a number of species, including *Diatraea saccharalis*, *D. canella* and *Rupela albinella* are causing some considerable damage, but the problem requires fuller investigation.

Padi Bug (*Solub poecila*)

This pest received the full attention of Mr. C. R. Wallace, Entomologist seconded from the Commonwealth Institute of Entomology. Mr. Wallace's final report is awaited and it is hoped that it will throw more light on the subject of grain blemish. The pest can be controlled by dusting with BHC.

The Rice Caterpillar (*Laphygma frugiperda*)

This is a pest of young nurseries for the most part and is normally controlled by flooding. Dusting or spraying with BHC formulations are also effective.

PESTS OF THE COCONUT

The Coconut Caterpillar (*Brassolis sophorae*)

Defoliation by this caterpillar is frequently spectacular and severely damaging to individual palms. Biological control keeps the pest under control to a large extent. Control measures by spraying or dusting are difficult to apply under prevailing conditions, and hand collection is carried out.

The Coconut Borer (*Castnia daedalis*)

The large larvae of this insect cause considerable damage on coconut plantations. No satisfactory control measure is known.

Acoushi Ants (*Atta* **spp.**)

These ants are extremely common and widespread on undeveloped or neglected land and control measures are essential prior to successful cultivation. Control measures using Cyanogas and carbon bisulphide have been replaced by chlordane. Methyl bromide proved even more effective, but is not so convenient nor safe as chlordane.

PESTS OF STORED PRODUCTS

A problem of major importance is the infestation of rice and other grain when in storage. The main species causing damage are the Lesser Grain Borer (*Rhizopertha dominica*), the Angoumois Grain Moth (*Sitotroga cerealella*) and the Rice Weevil (*Calandra oryzae*). The use of BHC dust has been of great assistance in bringing about control, but poor stores, storage at high moisture and infestation of clean grain from infested stores are the more important factors requiring attention. The fact that rice is stored for most of the time as padi unshelled and that all rice is parboiled in British Guiana, bring about a reduction in losses from pests.

CANADA

REVIEW OF ECONOMIC ENTOMOLOGY, 1948–1954*

Compiled by Robert Glen

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This report covers all fields of economic entomology except that of forest insects, for which a separate account is being given. The subject is reviewed under six main sections, each contributed by the appropriate unit head in the Entomology Division, as follows:—

Systematic Entomology (G. P. Holland) .. .. p. 189
Field Crop Insects (H. L. Seamans) .. .. p. 190
Fruit Insects (W. A. Ross) .. .. p. 193
Stored Product Insects (H. E. Gray) .. .. p. 198
Insects Affecting Man and Animals (C. R. Twinn) .. .. .. p. 199
Biological Control (A. B. Baird) .. .. p. 202

Space prohibits listing even the more important publications of the period. However, the bulk of entomological work in Canada is performed by officers of the Entomology and Forest Biology Divisions and their publications are listed in the annual reports of the Director of Science Service (Queen's Printer, Ottawa, Ont.), to which the interested reader is referred.

In general, entomology prospered as a profession from 1948 to 1954. Four regional entomological societies and a national professional body, the Entomological Society of Canada, were formed; the number of universities offering the Ph.D. degree with a major in entomology increased from 2 to 9; and an average of roughly 30 students per year graduated with entomology as their special field of interest. However, the number of such graduates declined from a high of 54 in both 1949 and 1950 to a low of 11 in 1953. This suggests that Canada may be entering a period of relative scarcity of trained personnel.

The varied insect activity of the past 6 years was featured by the gradual decline to insignificance of the grasshopper outbreak that began in 1930 in the Prairie Provinces. Other important developments included the increasing incidence of plant-parasitic nematodes, the rise of serious mite infestations following the general use of DDT in orchards, the outbreak of the rusty grain beetle in stored grain on the prairies, and the finding of some 50 pest species of insects not previously recorded from Canada.

Field activities centred on the many modern chemicals that have been registered for pest control. This produced, among other significant results, effective seed treatments for wireworm control, automatic concentrate sprayers for use in orchards, and an insight into some of the chemical and biological interrelations that confront the economic entomologist today. On the more purely biological side may be recorded the clarification of the species complex in root maggots infesting vegetables and cereals, an understanding of the biting-fly problem in the far north, the first introduction into Canada of insects for the control of noxious weeds, and significant additions to the Canadian National Collection of Insects.

Research facilities were greatly improved in most provinces, mainly by the construction of modern Science Service laboratories, a development that is continuing.

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* Excluding Forest Entomology.

This stimulated laboratory investigation on such subjects as temperature and moisture relationships, nutritional requirements, and the physiological basis of resistance to pesticides. Brief reference is made to one phase of this fundamental work in the paragraph that follows.

At the Science Service Laboratory, London, Ont., established in 1951, studies were begun on the modes of action of agricultural chemicals, the effects of the chemicals on the host plants, the course of breakdown of compounds, and the ecological effects of parent and breakdown products. The importance in mammalian toxicology of inhibition of the cholinesterase system by organophosphorus insecticides led to a study of this system in insects. The enzyme was shown to exist in soluble and in particulate form; activity of either form is markedly affected by salts, and this possibly explains certain discrepancies in the literature on this enzyme. Schradan acts as an inhibitor of cholinesterase, but weakly so *in vitro*. An active inhibitor resulting from the oxidation of schradan has been identified with the active compound produced by the metabolism of schradan both in insect species killed by schradan and in tolerant species. Schradan oxide is readily hydrolysed to non-toxic products and it is suggested that oxidation and hydrolysis occur in resistant insects at sites insensitive to the oxide.

SYSTEMATIC ENTOMOLOGY

Research in systematic entomology in Canada is conducted mainly by officers of the Systematic Entomology Unit of the Entomology Division. However, officers of other units, the Forest Biology Division, private individuals, and members of the staffs of several Canadian universities and other institutions have made noteworthy contributions during the period. The present short review deals particularly with the work of the Systematic Entomology Unit, but includes reference to the major contributions from other sources.

The Systematic Entomology Unit expanded rapidly during the period 1948–1954, scientific officers increasing from 6 to 21, with appropriate increases in supporting staff. The work of the Unit is considered under four headings, all more or less interrelated.

Canadian National Collection of Insects

The Canadian National Collection of Insects, the history of which scarcely exceeds 40 years, is maintained at Ottawa, although regional sections are established at several Science Service field laboratories. Between 1948 and 1954 the Collection grew at the rate of 100,000 to 150,000 specimens annually and now exceeds 2,000,000 pinned specimens, in some 5,500 drawers, in addition to material in liquid and on slides. It is strongest in Nearctic species, but contains a quantity of Palearctic and other exotic material. In recent years, emphasis has centred on collections of Pyralidae, Scolytidae, Siphonaptera, and severa families of Diptera.

Insect Surveys

Insect surveys were intensified between 1948 and 1954 and were the principal sources of material for the Canadian National Collection. Through the Northern Insect Survey, began in 1947, over 50 localities in Arctic and Subarctic Canada, Alaska and Greenland were investigated. This activity was concerned with all groups of insects, especially the biting flies, and a special effort was made to obtain pertinent ecological data. The Prairie Insect Survey, begun in 1948 as a regional study, provided much valuable material in such economic groups as grasshoppers, plant bugs, leafhoppers, and click beetles. Other special surveys in Canada and extra-limital collecting expeditions to the United States and Europe were undertaken by officers of the Unit to elucidate specific problems and to fill important gaps in reference collections. The Forest Insect Survey, conducted by the Forest Biology Division, Science Service, continued to be a most productive source of material, especially of forest pest species and their insect parasites (see report on forest insects).

Identification and Information Service

An identification and information service was continued for inquiring parties, who are usually economic entomologists of Science Service but may include other accredited individuals and institutions. This service, like the Collection, is strongest in the Nearctic fauna and in the major orders Hymenoptera, Diptera, Coleoptera, Lepidoptera, and Hemiptera, but includes also Trichoptera, Mecoptera, Siphonaptera, Orthoptera, Thysanoptera, Dermaptera, Isoptera, Collembola, and, to some extent, other minor orders. About 700 shipments of material comprising some 30,000 specimens, which involve the report of nearly 4,500 scientific names, are received and returned to the inquiring parties each year.

Research Projects

A research program was maintained in Coleoptera (especially Chrysomelidae, Elateridae, and Scolytidae), Lepidoptera (especially Rhopalocera, Phalaenidae, Pyralidae, and several groups of micros; tortricid and other larvae), Hymenoptera (especially Ichneumonoidea, Chalicidoidea, and other microhymenoptera, Symphyta, Vespidae, and Formicidae), Diptera (Nematocera, especially the blood-sucking groups, Tabanidae, and several groups of Muscoidea), Hemiptera (especially Cicadellidae, Aphididae, and Miridae), and Siphonaptera. In the period 1948–1954 officers of the Systematic Entomology Unit published approximately 115 papers, comprising more than 1,800 printed pages. The largest single contributions were a catalogue of Nearctic Chalcidoidea (in *U.S. Dept. Agr.*, *Agr. Monogr.* **2**, 1951), a revision of the Siphonaptera of Canada (*Canada Dept. Agr. Tech. Bull.*, **70**, 1949), and a monograph, " Larvae of the Elaterid Beetles of the Tribe Lepturoidini " (*Smithsonian Misc. Coll.*, **111** (11), 1950).

Of publications emanating from other institutions or from private individuals in Canada, special note should be made of Dr. E. M. Walker's revision of the Odonata of Canada and Alaska, the first volume of which, on Zygoptera, is now published (University of Toronto Press, 1953); Dr. J. McDunnough's revisions of *Eupithecia* and *Euxoa* (*Bull. Amer. Mus. Nat. Hist.*, **93** (8) 1949, and **95** (6), 1950) as well as his current work on *Hydriomena*; Dr. H. H. J. Nesbitt's large publication on Acari (*Zool. Verhandl.*, **12**, 1951); and Dr. F. Urquhart's popular book, *Introducing the Insect* (Clarke, Irwin & Co., Toronto, 1949).

FIELD CROP INSECTS

During the past 6 years the bulk of research on insect pests, particularly of species living in the soil, was concerned with the use of new organic insecticides, although relatively more attention was given to studies of biology than during the previous 6-year period. BHC, DDT and chlordane were used prior to 1948, but aldrin and dieldrin have since replaced chlordane for grasshopper control and with heptachlor have replaced BHC for wireworm and root maggot control in root crops where taint was encountered. Malathion and parathion have been combined with DDT for aphid control.

In the more purely biological studies the use of radio-active tracers to follow the movements of wireworms and cutworms in the soil and to determine the rate and distance of grasshopper dispersal in the field has added much to our knowledge. Investigation of aphid resistance in plants, particularly in peas, showed that resistance is associated with a low amino-acid and a high carbohydrate content. A second variety of wheat (Chinook) resistant to the wheat stem sawfly, *Cephus cinctus* Nort., was developed and is being distributed for planting in sawfly-infested areas. Nutritional studies on other insects provided much basic information on the requirements for development. The onion maggot, *Hylemyia antiqua* (Mg.), was reared aseptically on a purely chemical diet. Plant-parasitic nematodes were reared on pure cultures of fungi growing on agar plates, starting from a single gravid female to determine the range of individual variation and to obtain reliable specific characters.

Wireworms

Wireworms are probably the most widespread and generally destructive of the insect pests of field crops in Canada. BHC and lindane as seed and soil treatments gave excellent control, but where these compounds were used as soil treatments root crops could not be grown for at least 2 years without serious risk of taint. DDT did not give immediate crop protection from wireworms but over a period of years provided excellent control. Aldrin and chlordane were not quite so effective as BHC but gave satisfactory crop protection and control without tainting root crops.

European species of *Agriotes* were found on the east and west coasts of Canada. These are sedentary forms that do not spread out of the grasslands in which they are established. On the east coast they were apparently introduced with the soil that was used years ago as ballast by sailing vessels coming to Canada for cargo. In British Columbia the most serious infestation occurs at Agassiz, about 70 miles inland up the Fraser River, where at the turn of the century hop plants from England were planted on one farm and a few years later plants from this farm were moved to another about 3 miles away. A survey in 1952 showed that these were the only farms infested with *Agriotes obscurus* (L.) and the infestation was so severe as to cause the total loss of a crop of corn.

By tagging wireworms with radio-activity their vertical and horizontal movements in the soil were followed by means of a Geiger counter. The details were reported in *Science*, **111**, 5–6, 1950, and in the *Annual Report of the Entomological Society of Ontario*, pp. 7–15, 1950.

Grasshoppers

The wet seasons of 1951 and 1952 reduced populations of *Camnula pellucida* Scudd. and *Melanoplus* spp. in the Prairie Provinces to the lowest ebb since 1930. Control campaigns were not conducted in 1952 or 1953 but a slight increase in 1953 indicated the probability of minor local control being necessary in 1954. In British Columbia, grasshoppers increased in 1951, 1952, and 1953 on the grassland plateaux of the dry interior, necessitating extensive control programs. (A special report on grasshopper control is being prepared for the Conference.)

Grasshoppers in various stages of development were fed wheat treated with radio-active phosphorus and liberated on bare summer-fallowed fields to determine the rate, direction, and distance of dispersal where no food is available. Mortality from starvation, heat, and predators was very high, but at the end of 7 days 90 per cent. of the grasshoppers that were recovered had not moved beyond 100 yards from the release point and 37 per cent. were within 20 yards. Dispersal rate was greatest at winds of less than 5 miles per hour, immature forms moving into the wind and adult forms moving with it.

Cutworms

All varieties of field and garden crops in Canada are attacked by cutworms, of which there are many species. The great majority of pest species feed just below the soil surface, but some climb the plants and feed on the upper leaves during the night. Some rarely come to the soil surface; others move from plant to plant on the surface but burrow beneath to feed.

Excellent control of cutworms was obtained by using chlordane at 1½ pounds or dieldrin at a quarter of a pound per acre, sprayed or dusted on the soil surface. Where the sprinkler system of irrigation was used, the insecticides were introduced into the system and applied with the irrigation water. Poisoned bait, once the standard control recommendation, is rarely used today.

Root Maggots

Root maggots (*Hylemyia* spp.), including the carrot rust fly, *Psila rosae* (F.), are among the most serious pests of vegetables in Canada. Accordingly, investigations on species identity, life and seasonal histories, behaviour, and control were intensified, with the following results:—

1. The maggots attacking any one crop may be of one or several species.
2. Some species may have one or more generations a season, depending upon local conditions; but in some localities what appears to be several generations is really a sequence of different species.
3. Some species are distributed throughout the country; others are very restricted.
4. This biological complexity explains the contradictory control results previously obtained from different parts of Canada.
5. The more accurate knowledge of the species involved and the use of new insecticides have tended to stabilize control measures; seed treatments with DDT, chlordane, and aldrin have been effective in the control of the onion maggot, *Hylemyia antiqua* (Mg.), and of the seed-corn maggot, *Hylemyia cilicrura* (Rond.), attacking beans and cucumbers.

White Grubs

Pasture plots in Ontario treated in 1947 with 2½ pounds of gamma BHC per acre were still free of white grubs (*Phyllophaga* spp.) in 1953; beetles attempting to oviposit in the sod in 1953 were killed by the insecticide. Similar plots treated in 1950 with 1 pound of aldrin per acre were free of white grubs in 1953 and ovipositing beetles in 1953 were killed. Chlordane and DDT were not so effective for the same period but the few grubs surviving were not sufficient to cause noticeable damage. The insecticides were applied as sprays to the surface of the soil at the time the beetles were emerging. There was no subsequent cultivation to work the insecticide into the soil.

Aphids

The green peach aphid, *Myzus persicae* (Sulz.), attacked tobacco in southwestern Ontario for the first time in 1948, and has continued to be a serious pest. It not only injures the plants, but the honey dew on the leaves renders them unfit for use. Systemic insecticides provide an excellent control but cannot be recommended until more is known about residues in the tobacco. In the meantime, sprays and dusts of DDT or malathion are being used for control.

In New Brunswick the green peach aphid is the most important of the four species of aphid that attack potato, being the most abundant and the most effective transmitter of virus diseases. Sprays of DDT were very effective in reducing aphid infestations in New Brunswick but did not prevent the spread of viruses. However, in Prince Edward Island the potato aphid, *Macrosiphum solanifolii* (Ashm.), the most abundant species there, is more resistant to DDT and required a mixture of DDT and parathion for satisfactory control.

Plant Resistance to Insects

The control of the wheat stem sawfly, *Cephus cinctus* Nort., on the Canadian prairies is being accomplished by the development of resistant varieties of wheat, a co-operative project, involving entomologists, plant pathologists, and plant breeders. The first such variety developed, Rescue, has been grown for several years. A new variety, Chinook, is now available which though slightly less resistant to the sawfly is a better milling wheat than Rescue. These wheats have greatly reduced the annual losses caused by the sawfly and have also decreased the abundance of the pest.

In Quebec a variety of pea was developed that is resistant to the pea aphid, *Macrosiphum pisi* (Kltb.). Biochemical studies revealed that resistant varieties of peas contain a much lower amino-acid concentration than susceptible varieties. The reverse is true of the sugar concentrations. These quantitative differences in amino acids and sugars are believed to be important factors affecting resistance to aphids in different varieties of plants.

Some of the new corn varieties and some of the hybrid corns were shown to be resistant to attack and establishment by the European corn borer, *Pyrausta* *nubilalis* (Hbn.). Resistance in this case is largely mechanical; for example, the stems may be too hard for the borers to penetrate or too fibrous to be weakened by the few borers that become established.

Forage Crop Insects

Much of the research on insects affecting forage crops was on the species that affect seed production.

A European weevil, *Miccotrogus picirostris* (F.), first recorded from southwestern Ontario in 1939, was found to attack alsike, ladino, and white Dutch clovers, the larvae feeding within the seed. It now occurs throughout Canada.

In the Prairie Provinces, research on forage crop insects centred on species affecting alfalfa seed yields. This included the plant bugs that feed on the florets and green seed, and more particularly the wild bees that trip and cross-pollinate alfalfa. The leaf-cutter bees and bumble bees were most important, seed production depending on the retention of natural bee habitats near alfalfa seed fields. Under conditions prevailing in the Prairie Provinces, honey bees had no value in alfalfa seed production.

Wherever sweet clover is grown in Canada for forage or as green manure it is attacked by the sweet-clover weevil, *Sitona cylindricollis* Fahr. The most serious damage occurs to the seedling plants, which in Manitoba are frequently so severely injured as to require reseeding. A DDT spray or dust provided effective crop protection and ploughing sweetclover stubble in the autumn gave satisfactory control.

European Corn Borer

In southwestern Ontario the European corn borer, *Pyrausta nubilalis* (Hbn.), has been changing from a univoltine to a multivoltine strain. In the past few years the two-generation strain has become predominant, requiring a complete revision of control practices. Studies on genetics and photoperiodicity are being conducted to determine why this change has taken place. In the past 3 years the borer became established in southern Manitoba and Saskatchewan.

Nematodes

Two major projects on plant-parasitic nematodes were continued: the sugar-beet nematode, *Heterodera schachtii* Schmidt, in Ontario, and the potato-rot nematode, *Ditylenchus destructor* Thorne, in Prince Edward Island. Minor investigations were conducted on root-lesion nematodes affecting several varieties of plants.

Experiments with soil fumigation for the control of the sugar-beet nematode gave contradictory results. The most effective fumigant was DD, but when beets were planted too soon after treatment severe root distortion resulted. The best control was to keep beets out of infested fields for at least 3 years and to substitute crops on which the nematodes would not feed.

In Prince Edward Island the potato-root nematode was found to feed on clover, and potatoes grown on land that had recently been in pasture were frequently severely infested with the nematode. Potatoes damaged by the nematode usually contained fungi and most of the nematodes were found among these fungi instead of in the healthy potato tissue. In the laboratory the potato-rot nematode was reared on pure cultures of these fungi growing on agar plates in the absence of potato. Several pure lines of these nematodes are being reared, each starting with a single gravid female, to determine whether the potato-rot problem involves a single species of nematode or a complex of species.

FRUIT INSECTS

Research on fruit insects was conducted by the Entomology Division at Summerland and Victoria, B.C., Morden, Man., Vineland Station, Simcoe, and Harrow, Ont., St. Jean, P.Q., Fredericton, N.B., Kentville, N.S. Studies on insects attacking ornamentals and greenhouse plants were also undertaken at Victoria and Harrow, The new information obtained contributed greatly to the adequacy of the spray calendars that are published annually by the provincial departments of agriculture in all fruit growing provinces. The outstanding contributions were the development of concentrate sprayers and improvements in the harmonizing of chemical and biological control programs.

Concentrate Orchard Sprayers

The development of automatic concentrate sprayers for orchard use started in 1946 and advanced notably in 1948 when, with the aid of the British Columbia Department of Agriculture and the Suffield Experimental Station, Canada Department of National Defence, the Entomology Laboratory at Summerland, B.C. designed and constructed a light, automatic air-blast machine. A wide series of trials showed it to be suitable for use against the chief orchard pests at savings of about 75 per cent. in cost of labour and 25 per cent. in cost of spray chemicals. Within a year three commercially built concentrate sprayers were on the market. By 1953, with concentrate spraying general in some 4,000 orchards, this revolutionary method of applying pesticides had become more firmly established in British Columbia than in any other fruit growing area in the world.

The new method of spraying requires 70 to 100 gallons of spray liquid per acre of mature trees instead of 800 to 1,000 gallons, as customary in conventional spraying. During the 8 years concentrate spraying has been under study at Summerland, B.C., per acre dosages of spray chemicals have been modified as experiment and practical usage have indicated. Fruit growers, who no longer think in terms of pounds per 100 gallons but of pounds of toxicant per acre, are kept informed of these changes by means of the official spray chart.

There has been considerable variation in the efficiency of different makes of concentrate sprayers. However, the best of them have given control of insects and mites in British Columbia, Ontario, Quebec, and Nova Scotia equal to that from conventional machines.

Harmonizing Chemical and Natural Control

Studies on the interrelations of the apple orchard fauna and on the effects of spray materials on them have been under way in Nova Scotia since 1943. The results obtained include the following:—

1. Sulphur fungicides were highly detrimental to *Aphytis mytilaspidis* (LeB.) and *Hemisarcoptes malus* (Shimer), two important natural enemies of the oystershell scale, *Lepidosaphes ulmi* (L.). Because of this, their use for the control of apple scab resulted in serious outbreaks of the scale. Substituting copper, ferbam, or glyodin fungicides for sulphur allowed the natural enemies to increase to such an extent that *L. ulmi* was controlled by them in one to three years.
2. Sulphur, dinitro-o-cresol, dormant spray oils, tar oils, DDT, parathion and malathion drastically reduced populations of predators of phytophagous mites. Where these materials were avoided, the mites caused no appreciable damage.
3. The use of sulphur and of the arsenates of lead and calcium increased populations of the eye-spotted bud moth, *Spilonota ocellana* (D. & S.), especially when used over a period of years. DDT and parathion were lethal to both the bud moth and its natural enemies. On the other hand, nicotine sulphate and fixed nicotine, applied as under-leaf treatments when the eggs were hatching in mid-summer, controlled the bud moth without seriously interfering with biotic agents.
4. Sulphur, the arsenates of lead and calcium, dinitro-o-cresol as well as DDT, parathion, and other organic insecticides repressed the biotic control agents of the codling moth, *Carpocapsa pomonella* (L.), with serious consequences. However, in some Nova Scotia orchards the adoption of fungicides and other spray materials that do not seriously interfere with natural control made it possible to keep the codling moth to small proportions without resorting to

insecticides. Where natural control alone was insufficient, the addition of the botanical insecticide ryania was highly promising.
5. Many apple growers in Nova Scotia have adopted modified spray programs based on these findings and have obtained satisfactory results.

An investigation on the effects of spray chemicals on the fauna of peach orchards was started in 1947 in the Niagara Peninsula, Ont., with the following results to date:—

1. DDT usually caused a build-up in the population of the European red mite, due, in part at least, to the nearly complete destruction of its predators.
2. Sulphur reduced the populations of predators, especially *Typhlodromus* mites, with a consequent increase of the European red mite, although to a lesser extent than where DDT was used.
3. DDT greatly reduced the parasites of the cottony peach scale, *Pulvinaria amygdali* Ckll., and probably has been the main cause of the present outbreak of this insect.
4. There is no indication as yet that consistent control of the oriental fruit moth and the plum curculio on peach can be expected from biological control alone. Therefore, potent insecticides like DDT and parathion that are destructive to some natural enemies of these pests still have to be used.

Oriental Fruit Moth, *Grapholitha molesta* (Busck)

A severe outbreak of the oriental fruit moth on peach in Ontario from 1946 to 1949, following a long period of comparative scarcity, led to an intensive study of the effects of spray chemicals on this pest and its parasites.

Large scale field trials showed that good control could be secured by applying DDT to bearing peach trees, twice in July against the second generation, and once, about three to four weeks before harvest, against the third generation. The first two sprays were at the rate of 2 pounds of 50 per cent. DDT per 100 gallons, but in the last spray this was finally reduced to 1 pound to lower the residue at harvest to a safer level. Parathion was equally as effective as DDT, except that its shorter residual toxicity sometimes resulted in inadequate protection from the pre-harvest spray.

Most of the parasites of the oriental fruit moth continued to thrive despite the extensive use of these powerful insecticides. Actually, parasitism of twig-infesting larvae by the most important parasite, the imported species *Macrocentrus ancylivorus* Roh., was generally higher for the 5-year period during which DDT and parathion were used than for the 9 previous years.

The Plum Curculio, *Conotrachelus nenuphar* (Hbst.)

An extensive investigation of the plum curculio has been under way in Ontario since 1949.

Overwintering adults appear in the trees about the time plums are in full bloom, and some of them live throughout the summer and hibernate a second time. Egg laying starts when the shucks split and continues until about August 11. The summer brood of adults emerges from late in July until mid-September but does not produce a partial second generation in Ontario. Of two larval parasites recorded, the most effective is *Triaspis curculionis* (Fitch), which parasitizes up to 30 per cent. of the larvae.

Lead arsenate still gives satisfactory control of the curculio in many plum orchards, but, as it injures apricot and peach foliage and has not given satisfactory results in heavily infested orchards, other spray chemicals were investigated. EPN and parathion were the most effective of the phosphorus compounds, although Metacide and malathion gave fairly good commercial control; Compound 326 was of little value. All six chlorinated hydrocarbons tested, except aldrin, appeared to have longer residual action than most of the phosphorus compounds, Illoxol gave excellent control of the curculio but caused foliage and fruit injury on peach and plum; and methoxychlor rated high in southwestern Ontario as a spray on peach trees. Dieldrin is being recommended in 1954 for use on stone fruits in Ontario.

In 1948–1949 the status of the plum curculio in apple orchards in southwestern Quebec changed abruptly from that of a minor pest to one of great importance. No satisfactory explanation has been found. Under prevailing conditions, a calyx application and one cover spray of either dieldrin or methoxychlor gave satisfactory control.

Codling Moth, *Carpocapsa pomonella* (L.)

Generally speaking, wherever conditions are especially favourable for the codling moth no other insecticide proved to be so effective and economical as DDT. However, in British Columbia methoxychlor was also effective and is replacing DDT to some extent, particularly because it is less toxic to birds and mammals. In Nova Scotia, ryania appeared to be most promising as a selective insecticide for codling moth control as it is largely innocuous to natural enemies.

Preliminary studies in British Columbia indicated that, by adding a suitable surface-active agent to DDT wettable powder spray concentrate, the amount of 50 per cent. DDT may be reduced from 12 pounds per acre, as in the current recommendations, to 6 pounds without evident reduction in codling moth control.

Red-banded Leaf Roller, *Argyrotaenia velutinana* (Walker)

In 1948 the red-banded leaf roller came into prominence as a serious pest of apple orchards in Ontario and in 1951 outbreaks of it first appeared in Quebec. The remarkable and sudden build-up of this species and the change in its status to that of a major pest were associated with the introduction of DDT for codling moth control.

Two broods of the leaf roller were found in Quebec and Ontario and a partial third brood in the latter province. Satisfactory control was obtained from a single application of DDD 10 days after petal-fall. Against first- and second-brood larvae, malathion and parathion were effective, and lead arsenate in the calyx and 10-day sprays also gave satisfactory results.

Orchard Mites

Several species of mites have come to the front as serious orchard pests. The European red mite, *Metatetranychus ulmi* (Koch) [=*Paratetranychus pilosus* (C. & F.)], the most important species, the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, and the clover mite, *Bryobia praetiosa* Koch, are common both in the eastern provinces and in British Columbia, but in the latter there are two additional species, the Pacific mite, *Eotetranychus pacificus* (McG.), and the yellow spider mite, *Eotetranychus carpini borealis* (Ewing).

Extensive insectary and greenhouse investigations on 21 acaricides were conducted in Ontario since 1948. Sixteen of them were tried in the field on plum, peach, and apple; and Ovotran, Sulphenone, Aramite, and malathion were recommended for commercial use. Ovotran did not kill a high percentage of adult mites, but its pronounced ovicidal and residual effects resulted in excellent control, and it was compatible with all the commonly used spray materials. It caused slight injury on apple in British Columbia and Nova Scotia, but not in Ontario. The ovicidal and residual toxicities of Sulphenone were almost as high as those of Ovotran, but it was less effective in the field. Aramite had good residual action, but its ovicidal effect was poor, and it was not compatible with hydrated lime and bordeaux mixture. Malathion, although slightly less effective than parathion, was much lower in mammalian toxicity. EPN was as effective as parathion and had considerably greater residuality. Systox, with the longest residual toxicity, was the most effective of the phosphorus compounds. Uncertainty as to the health hazard it might create has so far prevented its use on fruit crops. The fungicide glyodin killed the active stages of the two-spotted spider mite except when used with the small amount of hydrated lime recommended by the manufacturer. It had no ovicidal or residual effect.

In a number of orchards in the Okanagan Valley of British Columbia, the European red mite showed resistance to the organic phosphates parathion and malathion. Resistant mites were controlled with Sulphenone, Ovotran, or Aramite.

Blueberry Insects

A comprehensive study of the life-histories and ecologies of insects affecting the low-bush blueberry in New Brunswick was begun in 1946.

The blueberry maggot, *Rhagoletis pomonella* (Walsh), was by far the most important pest discovered. Calcium arsenate dust was effective against it but unfortunately sometimes caused considerable burning of foliage. A really satisfactory control method has yet to be developed.

Over 50 species of lepidopterous larvae were observed, the most important being the cutworm, *Actebia fennica* (Tausch.), and the geometer, *Cingilia catenaria* (Drury). A 3 per cent. DDT dust at 40 pounds per acre for *A. fennica* and at 20 pounds for *C. catenaria* gave satisfactory control.

Other species encountered included the blueberry flea beetle, *Altica sylvia* Malloch, the blueberry thrips, *Frankliniella vaccinii* Morgan, and three non-economic species of sawflies.

Strawberry Insects

In New Brunswick the strawberry chlamys, *Chlamisus fragariae* Brown, a new strawberry pest, was first found in 1949. It was most abundant in 1951, was much less numerous in 1952, and was rare in 1953. Both the adults and larvae are voracious foliage feeders. A 3 per cent. DDT dust gave satisfactory control.

In British Columbia the white grub, *Polyphylla perversa* Csy., which previously forced many farmers to discontinue small fruit production, and the black vine weevil, *Brachyrhinus sulcatus* (F.), which caused serious losses in coastal areas, were satisfactorily controlled by the following method: before planting plough in to a depth of 6-8 inches 200 pounds per acre of 2½ per cent. dust of aldrin or 5 per cent. dust of chlordane and dust the roots of strawberry plants with either insecticide.

In Ontario parathion applied after most of the eggs had hatched was effective against the strawberry leaf roller, *Ancylis comptana fragariae* (W. & R.), a pest that was previously difficult to control with insecticides.

Insects and Mites attacking Greenhouse Vegetables

Since 1948 many changes have taken place in the methods of combating pests of greenhouse tomatoes and cucumbers. Organic chemicals with their superior toxicity to insects and mites have come into general use and aerosols and smokes have replaced spray and dust applications. In greenhouses with unusual width or in double ranges, aerosols cannot be used efficiently. In such cases smoke generators emitting tetraethyl dithionopyrophosphate or nicotine have given satisfaction.

Narcissus Bulb Fly, *Lampetia equestris* (F.)

During 1947–1949 the bulb industry in British Columbia was seriously affected by an outbreak of the narcissus bulb fly that resulted in infestations as high as 70 per cent. in some plantings. Extensive investigations revealed: (1) the larvae develop rapidly after the bulbs are harvested in July and destroy the flower parts by the first week of August; hence it is futile to treat the bulbs with hot water after they have been allowed to cure for two weeks; (2) fumigation with methyl bromide immediately after the bulbs are dug, at 3 pounds per 1,000 cubic feet for 4½ hours at 60° F., kills the larvae without affecting the quality of the forced blooms; and (3) the most practical field treatment is the application of aldrin, chlordane, dieldrin, or heptachlor as a dust over the bulbs after planting them in open furrows and before covering them with soil.

Highlights of the stored product insect work included widespread outbreaks in 1952 and 1953 of the rusty grain beetle, *Laemophloeus ferrugineus* (Steph.), in stored grain in western Canada, improved control for spider beetles in warehouses, the development of experimental equipment to simulate mechanical conditions in flour mills, and the establishment in 1949 of a small laboratory at Vancouver, B.C.

Outbreak of Stored Grain Pests

Infestations of the rusty grain beetle were noticed late in 1952 in a number of country elevators, elevator annexes, and bins on farms in Saskatchewan and Alberta. This condition arose primarily from the prolonged storage of some of the low grade wheat of the 1950 crop. The problem was aggravated by the restrictions of the quota delivery system, the prohibition on shipment of infested grain, lack of adequate storage to care for the large 1952 crop, unfavourable weather at harvest that resulted in the binning of grain containing excessive moisture, and the unseasonably mild weather in November and December that lengthened the period of high insect activity. During the winter and the following spring mites and fungus beetles became much more abundant than the rusty grain beetle. The situation was watched closely and the Stored Product Insect Unit of the Entomology Division collaborated with the provincial departments of agriculture, the Board of Grain Commissioners for Canada, the grain companies, and other agencies in holding losses to a minimum.

Spider Beetles

Spider beetles are the most important insect pests in flour storage warehouses in Canada. At least 12 species are present, those of economic importance being: the hairy spider beetle, *Ptinus villiger* (Reit.); *Ptinus raptor* Sturm; the Australian spider beetle, *Ptinus ocellus* Brown (=*P. tectus* of authors); and the white-marked spider beetle, *Ptinus fur* (L.).

The beetles emerge in the fall and are incapable of laying eggs until the following spring. Biology and control investigations revealed the following:—

1. All beetles exposed in sacks of flour or free in unheated warehouses were killed by winter temperatures. About 85 per cent. of those *under* the warehouse, hidden in débris and cracks in the floor supports close to the ground, survived, due to the more favourable temperatures there.
2. Temperature and relative humidity affect the incidence of larval diapause. Fifty-eight per cent. of the larvae that entered diapause were reared from eggs that were held at 25° C. and 47 per cent. R.H.; 30 per cent. from eggs held at 20° C. and 70 per cent. R.H.
3. DDT in oil, and as a water suspension, and BHC in oil gave good control; aluminium oxide and magnesium oxide as dusts were less satisfactory; and BHC as a smoke was ineffective. However, the less poisonous mixture of 2·5 per cent. piperonyl butoxide-pyrethrins (Pyrenone) in oil has been accepted by the millers, applications being made at 6-week intervals throughout the summer, commencing April 1.

Confused Flour Beetle, *Tribolium confusum* Duv.

Sanitation in flour mills received considerable attention with emphasis on the biology and control of the confused flour beetle.

Tailings and third low-grade flours gave four times the rate of beetle production obtained with first break stock and three times the rate with second middlings. However, adult survival was low on tailings and low-grade flours and high on middlings and break stocks. When free to choose their food, beetles preferred wheat middlings and flour containing 5 per cent. ground wheat germ. Although bran was relatively unattractive to adults, it was suitable for the development of larvae. The abundance of flour beetles in the feed end of flour mills apparently results from the mechanics of flour mill operation rather than from food preferences. Experiment and observation on distribution in flour mills showed no effect of parental feeding on the rate of development of the offspring.

Experimental milling equipment was constructed to simulate the conditions found in elevator boots and horizontal conveyors of several types of milling machinery. This was compared with the standard laboratory jar in studies of insect development and behaviour. The confused flour beetle required four to five times as long to complete development in moving flour as in stationary flour and the rate of oviposition was also markedly reduced in the former.

General fumigation of flour mills and food plants is expensive and few firms will do it more than twice annually. Spot or local fumigation is a necessary supplement. Experiments with spot fumigants showed an advantage in using materials with high toxicity and low vapour pressure to ensure prolonged effectiveness. Flour treated with hexachloropropene required 2 days to reach toxic concentrations but remained effective for over 2 months against beetles exposed for 48 hours.

Insecticides

The loss of DDT residues in box cars carrying flour for distances up to 1,400 miles was investigated. Losses were 10 per cent. greater from wood surfaces in contact with the commodity than from similar surfaces above the load level. Water suspension was the least satisfactory formulation, showing a 38 per cent. reduction. Car-lining paper, which is readily replaced, lost only about half as much toxicant as did plywood surfaces and provided a simple means of decontaminating the box cars of DDT on arrival at destination.

Paradichlorobenzene was effective against larvae of the webbing clothes moth, *Tineola bisselliella* (Hum.), and the black carpet beetle, *Attagenus piceus* (Oliv.), in a tightly sealed closet when high vapour concentrations were rapidly developed by heat or an air blast, only moderately effective when special vaporizing techniques were omitted, and ineffective when the closet was unsealed and in daily use. Naphthalene was ineffective as a closet fumigant against these pests.

Insect Haemocytes

Two projects were undertaken on insect blood cells. In the first, the haemocytes of the Mediterranean flour moth, *Ephestia kühniella* Zell., were investigated as possible sites of detoxification by comparing the normal blood cell picture with that of larvae recovering from the effects of various fumigants and certain other conditions of stress. Recovery was always accompanied by an increase in the total number of haemocytes, especially of cells apparently concerned in fat metabolism. In the second project the blood of 43 species representing 8 insect orders was studied in an effort to improve the existing classification of the haemocytes. In the lower orders, Orthoptera and Odonata, the cells were separable into 3 functional classes. The development of a fourth cell class became evident in the Plecoptera and was distinct in the higher orders.

INSECTS AFFECTING MAN AND ANIMALS

The Veterinary and Medical Entomology Unit of the Entomology Division was formed in 1952 to unify the direction of work formerly separated as Household and Medical Entomology and Livestock Insect Investigations. Research is conducted at Ottawa, Ont., Saskatoon, Sask., Lethbridge, Alta., and Kamloops, B.C. In 1953, Lethbridge was made the major centre in western Canada for livestock insect investigations.

During the period under review emphasis was given to the biting-fly problems in the north, the house-fly, warble flies, and the horn fly.

Biting Flies

The biology and control of blood-sucking flies that affect man and animals were studied in Canada by the Veterinary and Medical Entomology Unit in association with other agencies. These studies were performed largely on behalf of the Defence

Research Board, Canada Department of National Defence. Although special emphasis was given to biting-fly problems in the north, those in southern Canada also received attention; moreover, the results of much of the work have general application. More than 60 papers arising from these investigations have been published in scientific journals since 1948, reviews appearing in *Arctic*, **3**, 14–26, 1950, and in *Canadian Ent.*, **84**, 22–28, 1952. The results obtained include the following:—

1. About 60 species of mosquitoes in 8 genera have been recorded in Canada; 5 are genera represented in the Subarctic and 1 in the Arctic. The species most troublesome to man and animals belong to the genus *Aëdes*. The black flies (Simuliidae) in Canada include at least 60 species in 5 genera. Two widespread and abundant species, *Simulium venustum* Say and *Prosimulium hirtipes* Fries., are serious pests of man. Horse flies and deer flies (Tabanidae) are abundant in forested regions, especially in swampy forest. Of the several genera represented, *Tabanus* and *Chrysops* are the most important as pests of wild and domestic animals and, to a lesser extent, of man. Recent studies have revealed at least 20 species of biting midges (*Culicoides* spp.) in Canada.
2. The females as well as the males of *Aëdes* mosquitoes were found to feed on the nectar of flowers. Improved techniques in the use of the precipitin test to detect the source of blood meals of these and other blood-sucking insects were developed. In co-operation with Queen's University, progress was made in the use of the precipitin test in determining the insect predators of biting flies.
3. Methods of mass tagging of mosquitoes and black flies with radio-phosphorus, as a means of studying dispersal and flight range, were devised. A different approach, developed at the University of Alberta, involves studying the energy resources of some of the northern species in relation to their power requirements and efficiency in utilizing energy in flight.
4. Studies on the development and behaviour of *Aëdes* mosquitoes in relation to meteorological conditions at Churchill, Man., produced a method of predicting dates of emergence, an understanding of the effects of micro- and macro-environments on behaviour, and a device to utilize the visual responses of mosquitoes in trapping them.
5. Approximately 0·25 pounds of DDT per acre in fuel oil solution is effective against larvae and adults of mosquitoes and the adults of black flies. A dosage of 0·5 pounds of lindane per acre temporarily eliminated horse flies and deer flies in open forest; DDT and dieldrin were less effective against these insects. An effective device for applying DDT and other insecticides is a rotary brush unit that can be mounted beneath the fuselage or on the wings of aircraft.
6. The requirements for fine sprays and aerosols emitted from ground equipment to control adult biting flies were established by physical, chemical, and biological methods; the performances of four aerosol and two fine-spray machines were tested.
7. Tests on mosquito larvae and adults in various localities in Ontario showed no difference in susceptibility to DDT between mosquitoes from treated and untreated areas.
8. An efficient method of controlling black-fly larvae in streams without harming fish or materially damaging other aquatic life consists of applying DDT in fuel oil solution at a concentration of 1 part of DDT to 10,000,000 parts of water maintained at the point of application for 15 minutes. This method has been used successfully in many parts of Canada. The only larvicide found of comparable promise was a water suspension of heptachlor.
9. A method of laboratory screening of insect repellents with guineapigs instead of humans was developed. Absorption proved to be an important variable factor. With dimethyl phthalate, more repellent was lost by absorption through the skin than by evaporation.

House-fly, *Musca domestica* L.

DDT-resistance in the house-fly, *Musca domestica* L., was studied at Ottawa from 1949 to 1952 and the results published (*Canadian Ent.*, **85**, 340–346, 1953). Flies collected in nature at various points in Ontario and Quebec were reared at Ottawa through many generations and their susceptibilities to DDT compared with that of laboratory flies never exposed to insecticides. Whereas the average resistance of flies collected in 1949 was 20 times that of the laboratory flies, that of flies collected in the same areas in 1951 had increased to 2,000 times, even though chlordane, lindane, and methoxychlor had replaced DDT in these areas in 1950 and 1951. By 1952 strains resistant to DDT were found in localities in every province from Quebec to British Columbia.

Warble Flies, *Hypoderma* spp.

Two species of warble flies are widespread in Canada: the common cattle grub, *Hypoderma lineatum* (Vill.), and the northern cattle grub, *H. bovis* (L.).

Studies by the Ontario Department of Agriculture showed that, in areas of Ontario where warble control is compulsory, 2 or 3 applications of rotenone sprays or washes to the backs of cattle each season for several seasons caused a substantial and progressive reduction in the infestation of *H. bovis*; also that the rotenone in such sprays is highly toxic to swine, but not to other livestock.

In western Canada rotenone sprays have proved inadequate in protecting free-ranging herds, especially when only 1 application in a season is practicable. Accordingly, emphasis has recently been placed on ecological and physiological studies of the insects to obtain information on which to base improved control measures.

Preliminary attempts to rear the common cattle grub *in vitro* failed, but first-instar larvae survived up to 6 days in raw beef blood serum. Large numbers of flies were reared from mature grubs collected by fitting girdles on infested cattle. Field and flight-mill studies indicated that the flies require a pre-ovipositional flight, and that some are potentially capable of flying distances of up to 10 miles. Natural mortality of cattle warbles is high: it may approximate 50 per cent. of the grubs that reach the backs of the animals and may exceed 90 per cent. of those that emerge from the host. However, further reductions by chemical or other means are necessary to prevent economic loss.

Horn Fly, *Siphona irritans* (L.)

In co-operation with the Department of Bacteriology, University of Alberta, species of bacteria in the natural environment of the horn fly, *Siphona irritans* (L.), and associated with the various life stages were isolated and identified. This information was used in attempts, largely unsuccessful, to induce egg-laying by laboratory-reared horn flies.

Horn flies were controlled by spraying cattle at approximately 3-week intervals with a 0·5 per cent. water suspension of DDT. Range cattle were sprayed at the rate of about 2,000 per hour with an overhead boom and a V corral (*Agr. Inst. Rev.*, **8**, 18–20, 1953).

Other Livestock Insects

Horse bot larvae, *Gasterophilus* spp., were found to spend the first two instars in horses' tongues or in pus pockets between the teeth before reaching the intestines by being swallowed.

Unsuccessful attempts were made to rear the sheep ked, *Melophagus ovinus* (L.), in the laboratory. Spraying with 0·5 per cent. DDT or 0·25 per cent. chlordane was as effective as dipping in control. Dusting was satisfactory for treating feeder sheep in the autumn.

Twenty-eight species of ticks have been found in Canada, of which at least 6 are important pests of man and animals, especially in British Columbia. The Rocky Mountain wood tick, *Dermacentor andersoni* Stiles, is of particular importance as a vector of disease and cause of tick paralysis. Spraying cattle with 0·3 per cent. lindane or gamma BHC at 2 qt. per animal before turning them out on tick-infested ranges gave protection during the 6-week active tick season in the interior of British Columbia.

BIOLOGICAL CONTROL

The Biological Control Unit of the Entomology Division was established in April, 1948, to provide material and services in the biological control of noxious insects and weeds in Canada. In performing these services, the Unit co-operates with other units of the Entomology Division and with the Forest Zoology Unit of the Forest Biology Division, which is solely responsible for the investigation and use of diseases affecting forest insects. All biological control work in Canada is conducted by or in association with these federal agencies.

The Biological Control Unit has laboratories at Belleville and Kingston, Ont., Quebec, Que., and Vancouver, B.C. The Belleville laboratory, which has special quarantine facilities, is the centre for introductions from foreign countries and for the propagation of beneficial insects for release. A large modern laboratory, now under construction, will provide other needed facilities. The laboratories at Quebec and Vancouver deal with regional problems, including the release of beneficial organisms and the collection of established control agents for transfer to other areas. The Kingston laboratory has been headquarters for work on diseases of insects other than forest pests, but this activity will be transferred to Belleville upon completion of the new laboratory there.

Close collaboration with entomologists in the United States is maintained in all phases of this work, both foreign and domestic; and the Commonwealth Institute of Biological Control has rendered valuable service in obtaining parasite material from abroad. Where feasible, officers of the Unit participate in foreign work to broaden their knowledge and outlook and to provide on their return to Canada a source of information of special value in the solution of specific pest problems.

During the period under review, 52 species of parasites and predators and 2 species of phytophagous beetles were introduced for the control of some 16 insect and plant pests; and the special facilities at Belleville were utilized for various basic studies. A summary of the more important developments follows.

European Wheat Stem Sawfly, *Cephus pygmaeus* **L.**

The parasites *Collyria calcitrator* (Grav.) and *Pleurotropis benefica* Gahan, introduced from England in 1939 and 1940, became established in the heavily infested wheat fields in central Ontario and collections in the summer of 1948 showed an average parasitism of 45 per cent. over a considerable area. The following year parasitism reached a high of 82 per cent. and in 1950 adults of both species of parasites were very abundant in infested fields. Since then sawfly populations have been at such low levels that it has been difficult to collect larvae and those obtained each year have been heavily parasitized, chiefly by *C. calcitrator*.

Pea Moth, *Laspeyresia nigricana* **(Steph.)**

The parasites *Ascogaster quadridentata* Wesm. and *Glypta haesitator* Grav., introduced from England, continued as important factors in the control of this pest in British Columbia. *A. quadridentata* was transferred from British Columbia to Quebec and the Maritime Provinces in the early 1940's and was recovered in all areas of release between 1948 and 1951.

Grasshoppers, ***Camnula pellucida*** **(Scudd.) and** ***Melanoplus*** **spp.**

Three species of parasites, introduced from Argentina and released in Ontario and the Prairie Provinces between 1944 and 1948, were not recovered. Intensive studies of parasitism were continued in Canada and revealed that:—

1. In addition to egg parasites and predators, more than 20 species of primary parasites attack nymphal and adult grasshoppers; and in one area parasitism of *Melanoplus* spp. reached 98 per cent.
2. The percentage parasitism and the relative abundance of the species vary with the host complex, the season, and the crop.
3. The different species of parasites have definite host preferences but at low densities of preferred hosts the non-economic species are more heavily attacked and thus assist in maintaining the parasite populations.
4. An epizöotic disease in field populations is caused by the fungus *Empusa grylli* Fresenius. This disease attacked all common species except *M. m. mexicanus* (Sauss.), and all stages were infected except the eggs and first-instar nymphs. Some mortality was also caused by *Beauveria globulifera* (Speg.) Picard and a species of *Aspergillus*. Bacteria were common in all except the early instars but thus far no epizöotics of bacterial disease have been observed in the field.

Root Maggots, ***Hylemyia*** **spp.**

An investigation of the natural enemies of root maggots attacking cruciferous crops was begun in 1948 and carried out simultaneously in Canada and Europe. In 1953, material was also obtained from Japan. The abundance of parasites and predators varied with localities and years, but the major species are the same in all countries and their over-all effect on the host population is similar. Two species of parasites from Europe and one from Japan were released in small numbers in Canada. Studies are now being concentrated on predators that destroy the eggs and young maggots.

Carrot Rust Fly, ***Psila rosae*** **(F.)**

Unlike the root maggots attacking cruciferous crops, *P. rosae* has a number of important natural enemies in Europe that do not occur in Canada. Colonies of the parasites *Dacnusa gracilis* (Nees) and *Loxotropa tritoma* (Thoms.), obtained from England, were released in Ontario, British Columbia, and Prince Edward Island. A single specimen of *D. gracilis* collected in British Columbia is the only field recovery made to date.

Codling Moth, ***Carpocapsa pomonella*** **(L.)**

Work with parasites was temporarily discontinued following the widespread use of DDT. A bacterium, *Bacillus cereus* F. & F., was found to be highly pathogenic to codling moth larvae in all stages and preliminary field trials produced infection by spraying with spore suspensions. Experiments with this disease are being continued.

Larch Casebearer, ***Coleophora laricella*** **(Hbn.)**

Two species of parasites introduced from Europe, *Agathis pumilus* (Ratz.) and *Chrysocharis laricinellae* (Ratz.), have assisted in the control of the larch casebearer. Both species disperse slowly and only after a high degree of parasitization has been reached at the liberation point. In one area, which was studied intensively, samples taken at frequent intervals showed a narrow band of high parasitization moving radially from the liberation point and leaving behind it a much reduced casebearer population. The explanation seems to lie in the interrelations of the two parasite species: *A. pumilus*, which has a single generation annually, increases first, and *C. laricinellae*, with two generations, increases during the second generation as a secondary on *A. pumilus*; the progeny of this second generation and those of *A. pumilus* make a combined attack as primaries on the casebearer larvae the following year and destroy a high percentage of them.

Larch Sawfly, ***Pristiphora erichsonii*** **(Htg.)**

During the last decade the larch sawfly infestation increased in severity in the central region of Canada despite releases of large numbers of *Mesoleius tenthredinis* Morley, the imported parasite that previously was the most effective control agent in all infested localities. In this central area a large portion of the eggs deposited in the host larvae become encysted and fail to hatch. The phenomenon is being studied co-operatively with the Forest Biology Division.

Spruce Budworm, ***Choristoneura fumiferana*** **(Clem.)**

The damage caused by the spruce budworm has been so great that, although it is a native species, the possibilities of biological control have been extensively investigated. A serious effort was made to transfer from British Columbia to eastern Canada the biotic agents that did not occur in the east, where the pest was most destructive. Several species of parasites were thus transferred in considerable numbers, but only one species has given any indication of establishment. More recently predation by spiders has been investigated in British Columbia, where species of Salticidae were found to be of considerable importance. No transfers of spiders have been made to date. Natural enemies of related budworm species occurring in Europe were investigated and several species of parasites reared from *Choristoneura murinana* (Hbn.) and *Cacoecia histrionana* (Froel.), and a virus from the former, were introduced. None of these was recovered to date.

Balsam Woolly Aphid, ***Adelges piceae*** **(Ratz.)**

This European species caused serious damage to balsam fir, *Abies balsamea* (L.) Mill., in the Maritime Provinces. As a result of intensive investigations and collections in Europe, several species of important predators on the various stages were introduced and the following are now considered to be established in one or more areas: *Leucopis obscura* Hal., *Laricobius erichsonii* Rosenh., *Pullus impexus* (Muls.), *Cremifania nigrocellulata* Cz. The habits and spread of all species are being studied in Canada in co-operation with the Forest Biology Division and the work in Europe is undertaken by the Commonwealth Institute of Biological Control. Additional species are being obtained for release in 1954.

St. John's-wort, ***Hypericum perforatum*** **L.**

The biological control of weeds in Canada was first undertaken in 1951 with the introduction of the chrysomelid beetles *Chrysolina hyperici* (Forst.) and *Chrysolina gemellata* (Rossi) for control of the common St. John's-wort, *Hypericum perforatum* L., in British Columbia. This action followed the control of the weed in California by these beetles of European origin introduced from Australia. The beetles were collected in California, Oregon, and Idaho; and colonies were released during 1951 and 1952 in the Kootenay and Okanagan valleys. Establishment of both species at all points of release was confirmed in 1953.

Breeding of Insecticide-resistant Parasites

In 1948 officers at the Belleville laboratory undertook to produce a strain of *Macrocentrus ancylivorus* Roh. resistant to DDT as used in the control of the oriental fruit moth, *Grapholitha molesta* (Busck). As the action of DDT was found to be non-mutagenic, breeding involved continuous daily selection of a "tail" of survivors from many thousands of adult parasites produced from a continuous breeding unit. Each generation of parasites was exposed for 3 minutes to DDT on a thin film of celloidin in which concentrations of DDT crystals were deposited. During the first 9 months films containing 23 μgm. of pure p, p′ DDT per sq. cm. were used. Survival, initially 30 per cent., increased in 4 months to 80 per cent. and remained at this level until the DDT concentration was increased to 92 μgm. per sq. cm., when survival again fell to the 30 per cent. level and once more gradually increased to 80 per cent. Resistance of the parasites when last tested was about 10 times that of the original stock.

Nutritional Requirements of Parasites

Chemically defined diets and aseptic culture techniques were developed in nutritional studies centred on *Pseudosarcophaga affinis* (Fall.), a dipterous parasite of the spruce budworm, *Choristoneura fumiferana* (Clem.). The food medium consists mainly of pure amino acids, dextrose, cholesterol, ribonucleic acid, salts, and vitamins of the B-complex in a dilute solution of agar. The effects of over 60 chemical entities on growth were appraised and reveal that 10 amino acids, 6 vitamins, cholesterol, and phosphorus are essential and that a few other substances such as fats exert beneficial effects. Of the carbohydrates used, glycogen, starch, and sucrose were more effective than dextrose, levulose, dextrin, and melegitose, and no growth occurred with galactose. Three species of parasites and the house-fly, *Musca domestica* L., were developed from first-stage larvae to adults on this synthetic food.

CANADA

REVIEW OF FOREST ENTOMOLOGY, 1948–1953

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There has been very little change in the number of workers engaged in forest entomology in Canada during the five years under review. With the exception of university staff members in New Brunswick, Ontario, and British Columbia, and a few employees of provincial forestry departments in Quebec and Ontario, all persons engaged in forest entomology in Canada are members of the Forest Biology Division. They include 106 research officers, 67 technician assistants, 67 forest biology rangers, 37 clerical assistants, and about 100 seasonal employees (students and labourers), who are located in 11 laboratories in the various provinces, and in Divisional Headquarters at Ottawa.

The principal organizational change was the creation of the Forest Biology Division in 1951, out of two constituent units, the Forest Entomology Unit from the Entomology Division, and the Forest Pathology Unit from the Botany and Plant Pathology Division, of Science Service, Department of Agriculture.

This review is concerned solely with the forest entomological activities of the Forest Biology Division.

The Insect Pathology Laboratory at Sault Ste. Marie was put in operation in 1950, providing superior facilities for fundamental and applied aspects of the insect pathology program.*

New regional groups for forest entomological studies have been established at Corner Brook, Nfld., Debert, N.S., Quebec, P.Q., and Calgary, Alta. These new groups complement previously existing ones at Fredericton, N.B., Sault Ste. Marie, Ont., Winnipeg, Man., Indian Head, Sask., and Vernon and Victoria, B.C., so that the Forest Biology Division is now represented in each province, in its program of forest insect surveys and research. New laboratory buildings have been erected at Debert, Fredericton and Vernon, and one will be erected at Corner Brook in 1954. Seasonal field stations have been established in several regions of Canada.

FOREST INSECT SURVEY

The main emphasis in the Forest Insect Survey during its early years was placed on mapping outbreaks of major forest insect pests, and on compiling records of the distribution, and hosts and parasites of forest insects in general. The immature stages of most species were inadequately known and much effort was devoted to their identification and recognition; this task is a continuing project of the Forest Insect Survey.

A staff of " forest biology rangers " was employed to carry out the field aspects of the Forest Insect Survey, which had earlier depended almost entirely upon field officers of the provincial forestry services and the wood-using industries. There has been a gradual change in emphasis and in working arrangements within the Survey. To aid in the appreciation of long-term population trends, methods of establishing population levels more critically are being worked out. Specific collection schedules are being established, to give more precise data on the role of parasites and diseases;

* *Can. Dept. Agric., For. Biol. Div., Bi-Monthly Progress Report*, 6 (4), 1950.

and collection plots are being laid out in the more important forest types in each region. Additional research officers have been assigned to responsible posts in the regional survey centers. In addition to directing the general program of surveys, they carry out taxonomic, ecological, or biological control investigations relating to important forest insects of the region.

The annual volume of survey data has always presented a problem in analysis. In 1952, business machines utilizing punch card principles were employed by the Survey. The use of a standard code system in collecting and recording data, and of machine sorting techniques in their cataloguing and analysis, have made the records more accessible, and has improved the completeness and accuracy of newly acquired records.

Following creation of the Forest Biology Division in 1951, a forest disease survey was inaugurated and co-ordinated regionally and nationally with the insect survey. Continuity of principles, methods and aims is accomplished through the Co-ordinator of the Forest Insect and Disease Survey located at Divisional Headquarters in Ottawa. Reports of the Forest Insect and Disease Survey are published annually.

INSECT PATHOLOGY

The program of investigations in insect pathology includes fundamental studies of viruses, fungi, and bacteria attacking insects, a survey of diseases in forest insects in Canada, and experiments in biological control of field populations.

Insect viruses appear to go through a definite reproductive cycle (16), the virus particles multiplying in the free state in the cell nucleus, as well as within the polyhedral body (19, 25). Experiments have been initiated to learn more about the mode of reproduction within the host cell, using radioactive tracers. Changes in the virus-infected cell are also being studied by histological methods. In biochemical studies of insect viruses, a technique for analysis of amino acid components has been employed (138, 139) in comparing viruses from different insects (137), and in critical studies of the silkworm polyhedral virus. It has been shown that the virus particles, the membranes, and the polyhedral protein differ from one another in nitrogen, phosphorus, and amino acid content, and evidence is presented that the polyhedral protein is a by-product of the host, induced by virus infection (21). The nucleic acid content of 11 insect viruses has been investigated. The proportions of purine and pyrimidine bases vary in a balanced way, but no parallelism is evident between desoxyribonucleic acid composition and biological relationships (151).

Studies of entomogenous fungi have been concentrated on representatives of the genus *Beauveria*, which are commonly found in diseased insects. Owing to confusion in the genus, and in the related genus *Tritirachium*, extensive taxonomic studies have been in progress (91, 92). Although *Beauveria bassiana* causes heavy mortality in laboratory cultures of insects, it did not significantly increase mortality in field populations of the larch sawfly, when spores were disseminated on feeding larvae. Slightly more encouraging results were obtained when spore suspensions were applied to the ground just before larch sawfly larvae dropped to spin their cocoons. However, mortality due to *Beauveria* was only about 12 per cent (61, 93).

Many bacteria are associated with insects. The majority of species associated with the spruce budworm and the hemlock looper appear to be saprophytes, and the association is probably accidental (2, 127). Studies of the spore-forming *Bacillus sotto* have shown that a toxin, associated with crystalline inclusions in sporulating cells, causes paralysis in silkworm larvae within a few hours of ingestion. Spores freed of the crystalline inclusions by alkali treatment do not cause paralysis after ingestion, but are capable of causing septicaemia when injected into the body cavity. The alkaline supernatant causes paralysis shortly after ingestion, but apparently has no effect when injected into the body cavity. Untreated spores containing crystalline inclusions, when ingested by silkworm larvae, cause paralysis in 4 hours and septicaemia in 12 hours. It appears that toxic strains of *Bacillus* are those characterized by crystalline inclusions in the spores (3, 4).

Surveys of diseases in forest insects are carried out by members of the Insect Pathology Laboratory, utilizing suspect material supplied by the Forest Insect Survey, and by research officers engaged in ecological investigations in the various regional laboratories and field stations. A number of diseases affecting major forest insect species are referred to briefly in a later section.

The effective use of diseases, in biological control experiments against forest insects in Canada, has so far been confined to viruses. The influence of the fortuitously introduced polyhedral virus disease of *Gilpinia hercyniae* (Htg.) in the Maritime Provinces has been studied continually since the sawfly outbreak collapsed some 13 or 14 years ago (10). The virus has remained an efficient control factor, and in conjunction with introduced parasites which are somewhat more effective at low host densities, has prevented any important build-up of the sawfly in recent years (23, 107, 108). In 1950, the virus was introduced into an area near Sault Ste. Marie, Ontario, infested by a disease-free population of *Gilpinia.* Seven centrally located trees were sprayed with virus, and subsequently the incidence of disease was studied at successive distances from the " release " point. During the third subsequent generation of the sawfly, the maximum spread appeared to be 2,600 feet, the infection rate varying from 70 per cent at the center to less than 1 per cent at the periphery. The epizootics each year started from infection of a small number of larvae to which the disease was transmitted *via* the eggs laid by non-fatally infected adults (27, 30).

A polyhedral virus disease of *Neodiprion sertifer* (Geoffr.) was obtained from Sweden in 1949, and employed in field experiments for the biological control of infestations of this sawfly in southwestern Ontario during the following three years (24, 26, 28, 29). As a result of the successful experiments, aerial applications of virus suspensions were made on about 500 acres of infested plantations, and ground applications on about 200 acres of roadside plantings, by provincial authorities and property owners in 1953. These commercial applications were successful in killing high percentages of the sawfly populations. The disease is well established in the area infested by *Neodiprion sertifer*, and has maintained itself in experimental areas treated only once, in 1950 or subsequently.

Cytology and Genetics of Forest Insects

A small group of specialists is engaged in cytological and genetic studies of forest insects. Most of the investigations are carried out at Sault Ste. Marie, or elsewhere in Ontario, but the services of this section are available to research workers engaged in forest insect problems in all parts of Canada.

Cytological studies of two Buprestids, one attacking birch trees (*Betula* spp.), the other attacking poplar (*Populus* spp.), have confirmed ecological and morphological evidence that they are sibling species, *Agrilus anxius* Gory, and *Agrilus liragus* B. & B., respectively. The latter is the derivative species (12, 113). Extensive studies of beetle cytology have established principles governing evolutionary sequence in speciation within the group (114, 115).

Genetic studies to date have been concentrated primarily in the spruce budworm complex, utilizing stocks from various parts of Canada, as well as the jack pine budworm. Factors influencing the integrity of spruce and jack pine budworm populations in areas of overlap are referred to briefly in the discussion of the spruce budworm problem. Critical laboratory studies have been made of the rate of development, fecundity, and mortality of parental and hybrid stocks, and of the genetic basis of color variation in the moths (121, 122).

PHYSICAL ECOLOGY, BEHAVIOR, BIOCLIMATOLOGY

A number of Divisional research officers devote their full time to the investigation of the influence of physical factors on insect behavior, the extent of variation in temperature and other factors within insect habitats, and to broader problems of ecological meteorology and bioclimatology. The behavior of the spruce budworm has been studied intensively (62, 140, 141, 144, 147), and its bioclimatological relations have been outlined for the Great Lakes Region and the Maritime Provinces. Similar results have been obtained for the forest tent caterpillar. The reactions of caterpillars, sawfly larvae, and adult Diptera to various types of light, and the influence of temperature on their responses, have been investigated (125, 146, 149). Recent investigations of the white pine weevil include studies of the influence of physical factors on the rate of feeding, mating, ovipositing and development, and studies of the extent of variation in the physical environment in pine plantations and natural stands showing different rates of attack (123, 124). Radiation influences the temperature of insect micro-habitats. Differences between air temperatures and those of the micro-habitats and of the insects should be taken into account in critical studies of behavior, development and survival (64, 142, 143).

The studies are being extended to include mountain meteorology in relation to effects on insect populations and the host trees (63, 65), and to forest insect and disease problems in British Columbia.

REVIEW OF THE MORE IMPORTANT FOREST INSECT PROBLEMS

Only those problems of greatest interest during the period 1948–1953 are reviewed. Although references to numerous published papers are cited for the benefit of the reader, much of the recent work is still in report or manuscript form. Those interested in further details on infestations should consult reports of the forest insect and disease survey (52).

The spruce budworm is the most destructive forest insect in Canada. Its depredations are most serious in the eastern provinces, and the present review is confined to the budworm problem in the east. The larch sawfly has been most serious in central Canada in recent years. The lodgepole needle miner is confined to the Rocky Mountain National Parks. Forest tent caterpillar outbreaks have occurred from coast to coast, but the review is based primarily on conditions in Ontario, where more intensive work has been done than elsewhere. The other problems are primarily regional in character, as will be evident in the brief summaries.

The Balsam Woolly Aphid, *Adelges piceae* (Ratz.)

The balsam woolly aphid is an introduced pest of balsam fir in the Maritime Provinces and the northeastern United States. Trees are killed in two or three years by heavy attacks on the stem, and are stunted or killed slowly by attacks on the twigs. The salivary secretions of the insect cause " redwood," and the swollen twigs and abnormalities of the crown are known as " gout." The insect has been in Nova Scotia for 50 years or more. Spread has been gradual, and periodically severe winter temperatures reduce the population occurring above the snow line. Native predators are ineffective control agents, and no parasitic enemies are known. The European predator, *Leucopis obscura* Hal., was introduced at various times between 1933 and 1941, and spread rapidly throughout the infested area. Its searching ability is limited, it does not attack eggs and newly hatched nymphs, and becomes numerous only on heavily infested and severely injured trees (7, 36).

A search for additional predators was initiated in Europe in 1950 by the Commonwealth Institute of Biological Control and the Biological Control Unit of the Canadian Division of Entomology. Nine predators have been discovered, and shipments of five of these have been made to Canada. Four species have been liberated at selected points in the Maritime Provinces. Two of these, *Laricobius* *erichsoni* Rosenh. and *Scymnus impexus* Muls., have become well established in the release areas; small numbers of a third species, *Cremifania nigrocellulata* Czerny, have been seen subsequent to release, but it is uncertain whether the species is firmly established. The fourth species, *Aphidecta obliterata* (L.), has not been seen subsequent to release in 1951 and 1952.

Colonies of these and other predator species will be released in 1954. Studies of establishment, spread, and control value are being undertaken as part of the investigations of the population trends and ecology of *Adelges*. The Biological Control Unit is co-operating in the studies of establishment of imported species.

The Spruce Budworm, *Choristoneura fumiferana* (Clem.)

Most of the extensive budworm outbreaks which occurred in Ontario and western Quebec during the late 1930's and most of the 1940's have now largely subsided. One notable exception is the outbreak in northwestern Ontario, which presently occurs over an area of about 13,500 square miles, and comprises what had earlier been three separate outbreaks. Meanwhile, new outbreaks have appeared in the Gaspe Peninsula and adjacent parts of Quebec south of the St. Lawrence River, and in the Province of New Brunswick, totalling some 11,000 square miles in valuable pulpwood forests of balsam fir, *Abies balsamea* (L.) Mill., and white, red and black spruce, *Picea glauca* (Moench) Voss, *P. rubens* Sarg., and *P. mariana* (Mill.) B.S.P., respectively. Black spruce is relatively immune when growing in pure stands but occasionally is killed when growing in mixture with the other species.

Various methods of sampling budworm populations have been used for specific purposes. In short-term comparative studies, especially in stands where defoliation injury has not been serious, 15- or 18-inch branch tips, taken at fixed intervals along the crown, or at a given crown level, are satisfactory sample units for the determination of population density, degree of parasitism, or the effect of chemical control measures (31, 95, 134). In stands where defoliation injury has caused killing of twigs and the reduction of shoot growth, relative population density may be expressed in terms of numbers of budworms, in various stages, per 100 shoots of the current year, based on branches from different parts of the crown (50). In intensive studies of population distribution and density, trees may be lowered to the ground by block-and-tackle without undue disturbance of the budworm (31, 50).

These methods are quite satisfactory for successive samples during one or more seasons, until defoliation injury becomes so severe that the sample unit ceases to be comparable. In population studies continued throughout the course of an outbreak, or longer, it is more satisfactory if whole branches from standing trees are taken as the sample units. These should be distributed representatively throughout the tree crown, and area of branch surface recorded. This permits expression of budworm population in absolute terms, *e.g.*, number per 100 square feet of branch surface; or, by utilizing knowledge of crown structure of trees and number of trees per acre, it is possible to express populations in terms of number per tree or per acre. By recording the number of new shoots on representative whole branches, it is also possible to derive relative population density from the same material should this be desired (98, 103). Extensive egg counts in late summer are especially valuable for detecting the effect of moth dispersal, forecasting infestation and delimiting areas for aerial spraying operations. Areas of infestation are frequently so huge that economical methods must be used. A sequential sampling technique, utilizing comparatively few branches at each sampling station, and based on three levels of egg populations corresponding to the various degrees of defoliation injury anticipated in the following year, has been successfully employed in New Brunswick and Quebec. The method is designed to yield statistically acceptable data while eliminating unnecessary expenditure of effort (101).

In studies of the relation of spruce budworm outbreaks in central and eastern Canada to weather cycles, it has been shown that outbreaks are preceded by reductions, during three or four consecutive years, in the annual numbers of cyclonic centers passing through the affected areas, and in precipitation, particularly during June and July (148). These conditions of relatively dry, clear, early-summer weather, most suitable for budworm development, are produced in the Great Lakes Region by air masses of polar continental or polar maritime origin; and by a southward shift of the whole circulation pattern in the central part of the continent, which tends to block from the Great Lakes Region the more humid southwestern air masses (145). The analysis has recently been extended to the New Brunswick infestations. The outbreak which started in 1912 was quite widespread throughout the Province, and followed several years of general, dry, early-summer weather. The outbreak which started in 1949 was at first confined to the northern part of the Province, where dry, early-summer weather had been experienced for several years. Concurrently the southern part of the Province had experienced excessive precipitation, and this section was not infested until three or four years later (58).

The concept of " climatic release " has helped to explain in definitive terms the incidence in time and place of budworm outbreaks. However, susceptible forests are another prerequisite. For many years the " maturity " of balsam fir forests has been stressed as a factor leading to susceptibility, but only recently has there been an explanation of the " maturity factor ". Heavy and frequent production of flower crops is one important characteristic of mature fir forests. The male cones are the key to susceptibility. On bursting in the early spring, they provide succulent food for the newly emerged larvae before the vegetative buds have opened, and promote rapid larval development and higher survival. The persistent, cup-like bracts which remain after the male flowers have dropped are favoured hibernation sites of the newly hatched larvae in late summer. Significantly higher populations of eggs and young larvae occur on flowering than on non-flowering trees in the same stand. The physiologically mature trees therefore act as concentration points from which larvae in the latter part of the feeding stage, following exhaustion of the flowers and heavy defoliation, move down to consume the current foliage of smaller trees, including seedlings on the forest floor. Concentration of the population on the flowering trees occurs once more at oviposition, owing to their attractiveness to the female moths. In addition to this influence on stand susceptibility, flowering increases the vulnerability of the physiologically mature trees, owing to severe reduction in the quantity of new foliage produced in the flowering years, which occur annually or biennially (31, 50, 100).

Many factors influence budworm survival. Competition for new foliage is an important factor during outbreaks. Early seasonal exhaustion of new foliage, and consequent dependence on old foliage, lead to extensive dropping of larvae from the trees, greatly reduced larval survival, and reduced fecundity of the ensuing moths. Fecundity is quite variable during the course of an outbreak, and is capable of rising abruptly if the pressure of competition for new foliage in the late larval stages is reduced (31, 32, 103).

Among the biotic factors affecting survival, parasites and diseases have been studied most intensively. Over 70 species of native parasites attack the spruce budworm in its various stages (46, 95, 136). Generally less than half of this number occur in any one area, and most of them are relatively unimportant as control factors. In the Port Arthur district of Ontario, the effect of parasites on mortality of the larval and pupal instars, based on calculations of mortality/survival ratios (22), varied from about 30 to 50 per cent during the last year or two of vigorous infestation. Once serious declines had been initiated by starvation in the outbreak centers, mortality due to parasites rose to 80 per cent or more. In the peripheral areas of the outbreak in the Port Arthur district, starvation was not an important factor; nevertheless, population declines were only a year or two behind those in focal points, and were probably influenced by a multiplicity of factors, including less favorable forest cover, and the cessation of outward migrations from the outbreak center. Parasites became quite important in the peripheral areas after population decline had set in (94, 95).

Results of parasite studies in other areas are of interest. In one area, mortality due to parasites was 41, 31 and 13 per cent, respectively, in the third, fourth and fifth years of heavy infestation (94). In another area, mortality due to parasites was almost constant at 32 per cent. in the fourth, fifth and sixth years of heavy infestation. In a third area, mortality was 37, 25 and 31 per cent., respectively, in the sixth, seventh, and eighth years of heavy infestation (35). The egg parasite, *Trichogramma minutum* Riley, is usually not abundant, but was quite important in northwestern New Brunswick from 1948 to 1950. Thereafter its relative importance decreased as the host population increased. Strangely enough, there was also a decrease in absolute numbers of *Trichogramma*, possibly owing to scarcity of alternate hosts at times of the year when budworm eggs were not available (97).

Native parasites are incapable of preventing outbreaks, or of terminating them before serious damage is done to the stand. Parasite introductions into Eastern Canada from British Columbia and from Europe have been undertaken as a co-operative project of the Forest Biology Division and the Biological Control Unit. Except in the case of one species from British Columbia, there is as yet no evidence of establishment. Studies of budworm populations at release areas are being continued.

Disease in the budworm is caused by viruses, fungi, and protozoa. A polyhedral virus is widely distributed, but of minor importance as a mortality factor. In laboratory feeding tests using a polyhedral suspension, not all treated larvae died, and the proportion surviving was greater as the feeding time approached the onset of pupation. In injection tests using purified virus particles, the median lethal dose was found to be extremely high. Lack of effectiveness of the disease in nature appears to be due to a combination of low virulence of the virus, resistance of the host, and unfavorable circumstances for transmission arising from the feeding habits of the budworm (17). A capsule virus is also widespread in budworm populations. In northwestern New Brunswick, the infection rate was over 50 per cent. in 1953, but it caused no budworm mortality (103). Fungi of the genera *Beauveria*, *Empusa*, *Hirsutella*, *Isaria*, *Fusarium*, and *Acromonium* cause disease in the spruce budworm (89). There is little evidence of bacterial disease in the budworm. A protozoan disease was first reported in 1948 (53), and has been studied more intensively since that time. It is caused by a member of the genus *Perezia*. Quantitative studies of the role of diseases as control factors in field populations have been handicapped by difficulties in the diagnosis of the capsule virus, but in the Port Arthur district of Ontario larval mortality due to disease ranged from 22 to 29 per cent. in 1951 and 1952. About two-thirds of this mortality was caused by fungus diseases (127).

Useful qualitative and quasi-quantitative data have been gathered on individual biotic and abiotic factors by means of numerous, and frequently quite separate, laboratory and field investigations. However, this approach does not necessarily reveal the true significance of any individual factor, or group of related factors, in the epidemiology of the budworm. Since the forest stand itself is considered to be an important factor, it appears that the most satisfactory method of studying epidemiology of the budworm is to carry out investigations of all mortality factors in close integration with population measurements on an absolute basis, in each important stand type. Integrated studies of this type have been in progress in the Green River area of New Brunswick since 1944. Life tables have been prepared for each generation of the budworm for each stand type in which population data have been obtained. Only preliminary results have been published (103), since it is recognized that the data can be fully evaluated only after the outbreak has run its course. Among factors which had not been adequately studied previously, dispersion losses during the early larval stages are shown to be very important; starvation losses are heavy in areas with high initial population and hence early exhaustion of the new foliage; sex ratio and fecundity are entered in the life tables as " mortality factors "; and moth migrations frequently compensate for very heavy mortality of the resident population in a given stand. Passive dispersal of moths is not uncommon, and is characteristically associated with convective storms and cold frontal passages at the time of normal moth flight in infested forests (62). Transportation of moths in turbulent evening winds also occurs, and while probably of shorter duration than convective transport, the process could easily be repeated. Females deposited from these types of transport lay reduced numbers of eggs in the place of deposition, but the number of moths is frequently so great that egg populations in particular stands are greatly augmented. In other stands, expected egg populations are depleted (58).

The genetic relationships of the spruce budworm and the recently named jack pine budworm, *Choristoneura pinus* Free., have for several years been under investigation owing to recognized differences in seasonal and outbreak history, and the knowledge that under experimental conditions they can be induced to interbreed. The integrity of the two species in nature is maintained by ecological, temporal and sexual components of a complex reproductive isolation mechanism. Should the ecological and temporal barriers break down, and the sexual barrier be relaxed, natural hybridization would most likely occur between late emerging *fumiferana* females and early emerging *pinus* males. However, owing to genetically controlled eclosion times, the two sexes of the F_1 progeny of such unions would not emerge concurrently; rather, the F_1 males with the *fumiferana* females, and the F_1 females with the *pinus* males. Inbreeding of the hybrids would therefore be severely curtailed, and back-crossing into the two parent populations would be encouraged (116). Hybridization has not been observed in field populations of the two species, but in earlier studies the temporal barrier between them was essentially complete. Exceptional interest, therefore, attaches to the occurrence of overlapping populations of *fumiferana* and *pinus* in northwestern Ontario, where ecological barriers were only partially effective and where the temporal barrier broke down, in 1952. Considerable proportions of both sexes of both species eclosed concurrently, in the same area. Nevertheless, there was no hybridization among contemporaneous virgin moths. The sexual barrier is evidently that component of the reproductive isolation system that effectively maintains the integrity of the two species (117).

Dying of fir trees in the Port Arthur district of Ontario commenced in the fifth year of severe budworm infestation, after virtually complete loss of new foliage for five successive years. Fir mortality increased during the succeeding two or three years, and was generally at its maximum in a given stand about the eighth year after the first severe defoliation (13). Ten species of bark- and wood-inhabiting insects attacked severely weakened and dying fir trees, but only *Pityokteines sparsus* (Lec.) and *Monochamus scutellatus* Say were observed to attack trees before death was obvious (14). However, critical examination of the seasonal increment pattern, and of changes in foliar and cambial conditions, indicated that these insects played no part in the death of the defoliated trees. Mortality of fir was therefore attributed to the direct effects of severe, prolonged defoliation (13). In stands suffering virtually complete mortality of fir, the more vigorous trees were the last to die. In stands suffering only moderate mortality of fir, the more vigorous trees were those that survived (133). These results confirm conclusions reached in studies of budworm-affected stands in Quebec and New Brunswick some thirty years ago (43).

Mortality of white spruce was not so serious as that of fir during the budworm outbreak in the Port Arthur district. Following collapse of the outbreak in 1948, surviving white spruce trees put on good foliage growth in 1949, 1950 and 1951, and appeared to have recovered from the effects of prolonged budworm defoliation. Attacks by bark beetles, *Dendroctonus piceaperda* Hopk. and *Ips perturbatus* (Eich.) became apparent in 1951 and continued in the succeeding years over an area of some thousands of square miles. The affected area included peripheral stands where little mortality of spruce from budworm defoliation had occurred, as well as stands near the centre of the budworm outbreak where spruce mortality had been rather extensive. It appears that the beetle outbreak was encouraged by weakening of the host trees through defoliation (15, 126).

Following observations by earlier investigators (43, 57) on the apparent relation of severity of budworm damage to forest composition, attempts have been made to rate vulnerability in terms of stand characteristics. Westveld (150) conceived a vulnerability rating based on the product of merchantable fir volume (cords per acre) and the basal area of the average fir tree (square inches at breast height). Balch (5) defined susceptibility in terms of stand age, fir and spruce volume per acre, and percentage of fir in the stand; application of these ratings to large forest areas in New Brunswick, by means of photo-interpretation and rapid ground checks, has been described (102). The authors recognized that the validity of these rating systems could be judged only by events as an outbreak developed. In the meantime, the classification of forest stands by these systems drew attention to high-density stands which should receive priority in pre-salvage or salvage cutting operations.

These concepts of stand vulnerability were tested in the Algoma region of Ontario, which had experienced a destructive budworm outbreak from about 1936 to 1945. Mortality of fir was, in several localities, over 75 per cent., although the merchantable volume of fir was only three to five cords per acre, and comprised not more than 20 to 40 per cent. of the total stand volume. Both vulnerability rating systems failed to identify, as hazardous, stands in which mortality was in fact very high. A large proportion of severely damaged stands would have been rated, by these systems, as of low or medium vulnerability. While the results of this study do not encourage acceptance of vulnerability classes based on stand characteristics, they are not at variance with the basic concepts, because, in general, percentage fir mortality increased with basal area of fir per acre, relative height of fir, and the proportion of fir and spruce in the forest. However, these factors could not be combined in a meaningful vulnerability rating, owing to wholly unpredictable factors, particularly the intensity and duration of the outbreak. Location of a stand with reference to the focal point of an outbreak and to the successive bands of annual spread is quite as important as stand density and composition in determining the extent of mortality (129). Similar results have been noted in the Port Arthur district of Ontario (13).

Chemical control operations have recently been undertaken in an effort to prevent destruction of timber in particularly valuable fir-spruce stands. Following preliminary experiments in which DDT solutions were released over budworm infested forests in 1944, 1945, and 1946 (78), more intensive experimental studies were carried out in co-operation with Defence Research Board in the Kenora area of Ontario in 1951 and 1952 (75, 76). Among the more significant results, it was determined that lower spray deposits of DDT and reduced budworm mortality occurred on the downwind side of trees, in contrast with the upwind side, owing to screening effects of the foliage. Budworm mortality was not correlated with the volume of spray or with the size of the droplets reaching the ground in different parts of the experimental area; but it was correlated with the number of droplets, within the range of about 40 to 400 microns, per unit area. Two droplets per square centimeter produced 50 per cent. mortality; 12 droplets, 95 per cent. mortality; and 17 droplets or more, 100 per cent. mortality. Mortality was rapid in the two or three days following spraying, and increased gradually due to residual effect during the next five or six days. Third-instar larvae, protected within the buds of the host tree, were more difficult to kill at equivalent dosages than fourth- and fifth-instar larvae, which are less effectively protected by the foliage. In laboratory experiments sixth-instar larvae were more resistant to DDT sprays than earlier instars, but in the field trials they were readily killed.

Large-scale aerial spray operations were undertaken in New Brunswick in 1952 and 1953. Organization and financing were the responsibility of the pulp and paper companies, and the Provincial and Federal Governments. The Forest Biology Division provided technical advice and services, and undertook studies of the immediate and long-term effects of spraying on the budworm population and on the forest. The control of budworm outbreaks by aerial spraying does not appear to be feasible in the extensive fir-spruce forests of Quebec and New Brunswick, owing to initial population increase over very large areas, numerous and scattered infestation foci, and extensive dispersal of moths and young larvae before feeding commences in each generation. In these highly susceptible forests, annual increase in the area of heavily defoliated forest is frequently 5- or 10-fold during the first few years of an outbreak; and even greater, if lightly infested forests are taken into consideration. The policy has therefore been to spray only areas where defoliation has been severe for two or three years, and egg populations indicate continuation of heavy attack. The object is to prevent timber mortality in valuable stands.

In 1952, 12½ per cent. DDT in fuel oil was distributed over 300 square miles of infested forest, at the rate of one U.S. gallon per acre. Twenty-one spray aircraft were involved, and operated singly, utilizing a theoretical swath width of 100 feet. Spray distribution was checked by means of paper impregnated with oil-soluble dye (45, 48). It was necessary to respray only about 2 per cent. of the area (47). Effectiveness of the spray was about 99 per cent., judging by comparative populations on treated and check plots. Unfortunately, heavy moth flights from unsprayed portions of the 5,000 square mile infestation in northern New Brunswick resulted in heavy egg deposition in the sprayed area in late summer (8, 134).

In 1953, 77 aircraft distributed spray over 2,800 square miles, operating from six airfields. Since in 1952 there had been no evidence of unsatisfactory budworm mortality in areas with lower spray deposit, the theoretical dosage in 1953 was reduced to one-half U.S. gallon per acre. This was emitted from aircraft operating in pairs, at a separation distance of about 250 feet, and 150 feet between successive double swaths. Approximately one-quarter of the area, treated early when the budworm larvae were small and well protected, received a second application during the latter part of larval development (49, 51). Effectiveness of the spray, measured in terms of budworm population reduction, was about 87 per cent. in areas sprayed early, and only once; about 93 to 97 per cent. in areas sprayed twice; and about 99 per cent. in areas sprayed once only, but late in larval development. The greatest foliage protection occurred in areas sprayed twice, early and late in larval development; and the least foliage protection in areas sprayed only once, late in larval development. The area of infestation in New Brunswick was approximately doubled in 1953, and moth flights again resulted in reinfestation of the sprayed area, although to a lesser extent than in 1952 (11). Spraying operations will be continued in 1954, and will be concentrated on a 1,500 square mile area of young forest which succeeded the budworm outbreak of 1912–1919 in the Miramichi area of New Brunswick. This forest has been heavily defoliated since 1950 and 1951.

There is no basis at the present time to regard spraying operations as a solution to the budworm problem in eastern Canada. At most, they may preserve valuable forests during a period of outbreak. In northwestern Ontario, fir-spruce forests are not so extensive as in Quebec and New Brunswick, and focal centers of outbreaks appear to be more sharply defined. In the future, with intensive annual surveys in known susceptible forests, it may be possible to detect the initial stages of an outbreak and to delineate it more accurately than in the past. If this can be done, the possibility of checking a developing outbreak by chemical control operations should be investigated.

Destructive outbreaks do not permanently reduce the hazard; they merely defer the next period of hazard until the succeeding coniferous stand, with an equally high balsam fir content, of relatively uniform age over large areas, reaches maturity. Studies in northwestern Ontario (34) show that successive outbreaks are closely associated with maturity and increasing dominance of balsam fir in the forest. The occurrence of the first outbreak did nothing to lessen the intensity of the second, some 70 years later, over substantially the same area in northwestern Ontario. Shorter intervals between outbreaks have been recorded where the original stand was not so completely destroyed, and hence remained susceptible. The aim must therefore be to reduce hazard, through silvicultural management, including adoption of short rotations for balsam fir, maintaining vigor, avoidance of extensive stands of even-aged mature or overmature fir, and increasing the proportion of other species. In the absence of extensive stands under silvicultural management in eastern Canada, the belief that these measures will bring increased protection against the budworm is based largely on presumptive evidence drawn from investigations, surveys, and observations (9, 99, 105). One of the important features of the Green River Project in New Brunswick is the long-term study of budworm population dynamics and resultant damage in stands of different types and under different silvicultural treatments (6, 99).

The Lodgepole Needle Miner, *Recurvaria* sp.

The needle-miner outbreak in the Rocky Mountain National Parks was first discovered in 1942, over an area of approximately 50 square miles near Banff. In the following 7 years the outbreak enlarged to about 450 square miles, comprising sections of Banff, Kootenay, Yoho, and Jasper National Parks. Since 1950 there has been a slight reduction in the infested area, following extensive winterkill of the hibernating insects in the winter of 1949–1950. In heavy infestations, 50 per cent or more of the needles of lodgepole pine are mined by the insect. In spite of the prolonged infestation, there has been little or no tree mortality, but there has been a marked reduction in shoot growth and in radial increment.

The life history, habits, and natural control factors have been studied since 1948 (120). The insect has a two-year life-cycle, moths appearing in the even-numbered years. Larval development proceeds from the autumn of one even-numbered year until the early summer of the second following year, and each larva mines three needles during this period. Foliage injury is most conspicuous in the early summer of the moth-flight year. There is apparently very little deviation from the normal developmental cycle related to the even-numbered years. Mortality caused by parasites, of which there are 15 species, has not exceeded 30 per cent to date. Mortality caused by low winter temperatures is normally about 20 per cent during each of the two overwintering periods, and would therefore account for about 35 per cent of the population of each generation. However, there are differences due to altitude and to variations in air circulation patterns over the mountains; mortality in the severe winter of 1949–1950 was almost complete in the valley bottoms (elevation 4,500 to 5,000 feet), and varied from 30 to 90 per cent along the slopes some 1,000 to 1,500 feet above the valley bottoms (65). Repopulation of the valley bottoms was gradual after the heavy kill of 1949–1950.

Reliable sampling techniques have been developed for intensive ecological and population studies of the needle-miner and its parasites, and for more extensive surveys of infestation status throughout the infested area (118, 119).

The future of the outbreak and of the infested stands cannot be forecast. Recurrent severe winters would cause periodic curtailment of the infestation. The onset of a drought period might have serious consequences on the weakened stands, rendering them susceptible to the bark beetle, *Dendroctonus monticolae* Hopk., which occurred in outbreak numbers about 10 years ago. Studies of the endemic *Dendroctonus* population are being resumed in 1954.

Chemical control offers little or no promise, owing to concealed habits of the needle miner and the mountainous terrain. Parasites collected by the Biological Control Unit from needle-miner infestations in the western states have been released in the Canadian infestation, but so far as is presently known, the species are identical with those occurring naturally in Canada. A capsule virus, also recovered by the Biological Control Unit in the western states, has been put out on a number of experimental trees, but authentic data on the results are not yet available.

The Larch Sawfly, *Pristiphora erichsonii* (Htg.)

Within the last 10 years or more, heavy infestations of the larch sawfly have spread over the vast area extending from northern Ontario to Alberta, and southward to the north-central States. The earliest centers of infestation appear to have been in Manitoba (81). Most of the larch stands in the affected area are young, having succeeded the mature stands killed by sawfly outbreaks about 35 years ago. Few trees have been killed by the current outbreaks, although repeated defoliation has resulted in marked reduction of shoot growth and radial increment (70, 81, 88, 131).

The development of these outbreaks seems to be related to a marked decline in the effectiveness of *Mesoleius tenthredinis* Morley as a biological control factor in this region of North America. A high proportion of the *Mesoleius* eggs deposited in sawfly larvae in this region fail to hatch, owing to encapsulation (104). The extent of the failure to hatch is variable, but in general limits effective parasitism to less than 5 per cent. of the sawfly population (72, 87). This reaction of the regional sawfly population to *Mesoleius* has evidently developed, or at least has become widespread, since 1927, when high effective parasitism in the region was last recorded (44). The latest records on *Mesoleius* as a control factor of the sawfly in British Columbia and in the Maritime Provinces suggest no reduction in its effectiveness (73, 74, 96, 109). Only a small proportion of a laboratory culture of British Columbia sawflies encapsulated *Mesoleius* eggs deposited in them. Evidently the immunity reaction is an attribute of the sawfly population, although temperature and health of the host influence the degree of its expression (87, 104).

Bessa harveyi (Tn.) is the most effective parasite of the sawfly in the central region of Canada. This species was absent or very rare until releases were made between 1939 and 1942, but it has built up gradually in new sawfly infestations, usually reaching maximum effectiveness 5 to 8 years after initial recovery in an area, or approximately 3 to 5 years after the sawfly infestation has reached its peak. Effective parasitism reached 30 to 50 per cent. during peak years of heavy infestations, and has remained at moderate levels in the declining phases of an infestation (71, 82, 86, 87).

Tritneptis klugii (Ratz.) occurs in Manitoba and Saskatchewan, but parasitism of sawfly cocoons is generally less than 5 per cent. In co-operation with the Biological Control Unit of the Division of Entomology, releases were made in 1948, 1949, and 1952, but recovery has been made from only one release area. Small numbers of 7 or 8 other species of parasites have been recovered from sawfly cocoons in Manitoba and Saskatchewan, but they are negligible as natural control factors (87).

Diseases of the larch sawfly have been investigated more intensively in northwestern Ontario than elsewhere in Canada. Entomogenous fungi (*Beauveria* sp., *Empusa* sp., *Isaria* sp., *Fusarium* sp., and *Spicaria* sp.) and the bacterium, *Bacillus cereus* Fr. & Fr., rarely cause more than 5 per cent. mortality in the feeding stages, although *Empusa* sp. occasionally causes high mortality in very dense sawfly populations. Mortality from disease is somewhat higher among cocoons, and ranged from 7 to 28 per cent. over a four-year period. There is evidence that strains of *Bacillus cereus* vary in their capacity to produce the enzyme lecithinase, and that this capacity is related to pathogenicity for the larch sawfly. One pathogenic strain causes toxaemia in the larvae, and is more effective at higher temperatures (60, 61).

No evidence of a virus disease in larch sawfly populations in central Canada has been found.

Recently recorded predators of the feeding larvae include mirid bugs, spiders, and mites (130), and several species of birds (39). The swamp sparrow has the peculiar habit of decapitating the larvae, swallowing the head but discarding the body (59) Full-grown larvae dropping to the ground for spinning are eaten by frogs, mice and shrews (37, 38).

Sawfly cocoons are opened by mice and shrews from late August to early November, but very few are destroyed by small mammals at other periods (40).

The red-backed vole, the field vole, and the cinereous shrew tend to avoid cocoons containing *Bessa* larvae. Estimates of predation from spinning in the late summer until emergence the following year, based on cocoons " planted " in heavily infested larch stands in eastern Manitoba in 1952 and 1953, varied from 48 per cent. to over 97 per cent. (41).

The growth responses of larch trees have apparently limited the period of severe infestation during the current outbreaks. Severe defoliation results in progressive reduction of the amount of foliage produced annually, and in the number and size of new shoots suitable for oviposition (82, 131). The production of substitute shoots by injured trees may partially offset the reduced number and size of normal shoots suitable for oviposition, but the reduced quantity of foliage on the old twigs increases the probability of larval starvation in heavy infestations (68). About 80 per cent. of the total food consumption occurs in the last larval stage (67), and in heavy infestations trees are frequently completely stripped. Under experimental conditions, last instar larvae exposed to starvation for 4 or 5 days suffered heavy mortality, and the survivors a deficit of over one-half in dry weight, and over three-quarters in lipid content, compared with fully fed controls. In field populations, only those larvae dropping from the trees after defoliation reached or exceeded 90 per cent. showed significant weight losses due to defoliation. The influence of partial starvation on fecundity is being investigated (66, 69).

Immersion of cocoons in water has variable results, depending on the time of immersion. Larvae in newly spun cocoons may succumb to flooding for one or two weeks in late summer. Resistance to immersion increases with ageing of the cocoon and the entrance of the larva into diapause. In late fall and early spring the dormant larvae within the cocoons withstand immersion for several weeks. Resistance drops as the insect resumes development within the cocoon in late spring and early summer, and immersion at that time for only a few days causes heavy mortality (42, 85). High water levels in larch swamps may result in reduced infestations and damage (84).

Relative mortality rates in the different life stages, caused by the above-noted factors, can be appraised by sampling methods based on " curled tips " and branches for the egg and feeding larval stages; partial or complete trays for fully grown larvae dropping from the trees; and on cocoon " plants " or selected samples of the cocoon population (41, 61, 77, 87). The extremely variable ground conditions in larch swamps present an obstacle to reliable cocoon population estimates which has not yet been overcome. The loss of dropping mature larvae, through drowning and predation before spinning of the cocoons, has not been measured. Hence it is difficult to collate the data relating to mortality in the tree-inhabiting and the ground-inhabiting stages in the life-cycle. The most important factors influencing population trend appear to be small mammal predators, *Bessa harveyi*, reduced oviposition sites and foliage supply resulting from previous defoliation, and high water levels in the swamps.

The prospect of reducing the severity of infestations through silvicultural measures is not encouraging, since the sawfly attacks all types of larch stands without apparent discrimination. Future widespread mortality of larch stands will probably be experienced as the present stands approach maturity more or less simultaneously. A greater diversity of age-classes, through prompt harvest cuttings as soon as merchantable size is attained, would be advantageous (83). Aerial spraying operations may be effective in protecting the more valuable stands (81), but will probably not be practicable as a general measure, owing to the relatively small size and scattered distribution of larch stands in the region.

In co-operation with the Biological Control Unit and the Commonwealth Institute of Biological Control, the Forest Biology Division is continuing the search for additional parasites in England and on the continent. A special search is being undertaken for a virus disease of the sawfly. Meanwhile, ecological and natural control studies are continuing in Canada, and special attention is being given to the interrelations of *Mesoleius* and local sawfly populations in different regions.

The Forest Tent Caterpillar, *Malacosoma disstria* Hbn.

During the last 5 years, the forest tent caterpillar has been in outbreak phase over tremendous areas from the Maritime Provinces to Saskatchewan. More limited outbreaks have also occurred in Alberta and British Columbia. Stands of trembling aspen, *Populus tremuloides* Michx., and largetooth aspen, *Populus grandidentata* Michx., aggregating hundreds of thousands of square miles, have been completely denuded for 3 to 4 or 5 consecutive years, as well as stands of sugar maple, *Acer saccharum* Marsh., red oak, *Quercus borealis* Michx. f., and other hardwoods, throughout their more restricted distribution range. The outbreaks attracted wide public attention, owing to defoliation along highways, in cities, towns and resort areas; mass migrations of caterpillars which interfered with road and rail traffic; and massive moth flights which were attracted to street lights and lighted store windows.

Denuded trees refoliated, in part, after feeding ceased each year. Except for occasional dead trees on poor sites, injury is generally limited to partial killing of tree crowns and sharply reduced annual increment in stands which were infested most severely.

Repeated outbreaks of the forest tent caterpillar have been recorded at intervals of approximately 10 years. In the Great Lakes Region of Ontario, the commencement of outbreaks coincides with increase toward an annual maximum, in the frequency of cyclonic centers passing over the area, and particularly with an above-average number of passages in spring and summer. The air masses providing suitable conditions for forest tent caterpillar outbreaks are of southern or southwestern origin (145).

Studies of population levels and of natural control factors have been undertaken in the infested regions during the current outbreaks. Fungus diseases of the forest tent caterpillar are caused by *Beauveria* sp. and *Empusa* sp., the latter occasionally causing considerable mortality (90). Disease caused by bacteria has been noted generally in field collections, but at a low incidence; apparently conditions of overcrowding, partial starvation, and high humidity favor bacterial disease (1). An unidentified protozoan disease has been widely recovered in Ontario, and in laboratory rearings may cause heavy mortality (111).

A polyhedral virus disease has been recovered very generally throughout infested areas in Canada. In laboratory feeding experiments with healthy field-collected caterpillars, resistance to the polyhedral virus was high (18). Nevertheless, very high incidence of polyhedral virus disease has been noted in some localities; mortality being heavier in sugar maple stands than in aspen stands in the immediate vicinity. Laboratory feeding experiments indicated a greater susceptibility to virus disease of forest tent caterpillars fed on oak in contrast to those fed on aspen (111).

Over-population is typical of severe forest tent caterpillar outbreaks. Whereas the larvae emerging from about 10 egg bands are sufficient to completely defoliate moderate size aspen trees, in many areas the number of egg bands per tree exceeded 100, and instances of 500 to 900 bands were recorded during the peak years.

Some 15 species of parasites attack the forest tent caterpillar, the most important being *Sarcophaga aldrichi* Park., *Euexorista futilis* (O.S.), and *Leschenaultia exul* (Tn.). The host population may continue to increase even with an aggregate parasitism as high as 50 per cent. or more, in the second or third year of outbreak. In static or declining host populations, aggregate parasitism frequently reaches 95 to 99 per cent., just before collapse (112).

Populations over a large area in northwestern Ontario and southeastern Manitoba were destroyed by unusual weather in 1953. Hatching was hastened by warm weather in early May, feeding started on the newly opened foliage and there followed a 3-week cold, wet period, with temperatures below freezing and heavy rainfall. Mortality appeared to be due to a combination of freezing and starvation, circumstances differing somewhat throughout the affected area. Disease and parasitism later killed most of the small percentage of the original population which survived unfavorable weather conditions.

Round-headed Borers (Cerambycidae)

Cerambycid borers cause serious value loss in fire-killed and insect-killed timber before salvage is possible, and also in sawlogs stranded in the woods during the summer. Unsatisfactory haul roads and poor stream-driving conditions periodically result in summer stranding of sawlogs in eastern Canada. Experiments in the prevention of attack by DDT sprays applied to skidways of jack pine, spruce and balsam logs in northwestern Ontario indicated that DDT-oil sprays were effective in reducing attack by 86 to 98 per cent. Sprays of water-wetable DDT were not so effective, particularly in rainy seasons (33). DDT-oil sprays have been effectively used for protection of white and red pine logs by commercial operators, with technical assistance from the Forest Biology Division.

Ambrosia Beetles

Five species of ambrosia beetles attack Douglas fir, hemlock, and other softwood logs in the coastal area of British Columbia. Attack occurs in the early spring and summer, and the exposed surface of logs floating in the water is subject to attack, as well as logs on the ground or in cold-deck piles. Loss through degrade is especially serious in peeler logs for veneer manufacture. *Trypodendron cavifrons* (Mannh.) and *Gnathotrichus sulcatus* (Lec.) are the most abundant and destructive species. *Trypodendron* galleries penetrate to a depth of 3 inches or more, and there is a fairly consistent relation between the density of attack (entrance holes per square foot) and the number of galleries appearing on the edge-grain surface of lumber cut from infested logs (55).

Experiments in the use of chemical sprays to prevent attacks in newly felled Douglas fir logs in July, 1950, indicated that a spray of BHC plus benzene in fuel oil was effective in preventing attack by *Gnathotrichus*. Emulsions of BHC were essentially as satisfactory as the oil spray (80). An emulsion spray of BHC was applied to floating Douglas fir logs in May, 1952, and appeared to give satisfactory protection (56). Nevertheless, extremely poor results were obtained when BHC emulsion was applied to western hemlock and Douglas fir logs, on a commercial scale, in 1953. Very heavy attacks of *Trypodendron* occurred within 3 weeks of the period of spraying (54).

More critical experiments in chemical control of ambrosia beetles in British Columbia are being undertaken in 1954, in conjunction with investigations of the behavior and bionomics of the various species.

Bark Beetles (Scolytidae)

Infestations of several species of bark beetles have occurred in Canada during the last 5 years. *Dendroctonus piceaperda* Hopk. and *Ips perturbatus* (Eich.) have built up in the Port Arthur district of Ontario, attacking white spruce trees which survived the recent budworm outbreak in that area (see under spruce budworm). *Dendroctonus monticolae* Hopk. has caused heavy mortality of lodgepole pine in parts of the East Kootenay district of British Columbia. *Dendroctonus engelmanni* Hopk. populations increased in the Vernon area of British Columbia, attacking wind-thrown and standing trees in an area where experimental logging operations were being carried out. A high percentage of the trees of larger diameter were killed (128). *Dendroctonus pseudotsugae*

Hopk. attacks in Douglas fir in the south-central part of British Columbia have assumed increasing importance. Investigations of the behavior and bionomics of the beetles, and the silvicultural aspects of these problems, are continuing.

Experiments in the chemical control of *Dendroctonus monticolae* broods in lodgepole pine trees were carried out in 1951 and 1952. At dosages of 20 pounds of active ingredient per 100 gallons of 20 per cent. oil-in-water emulsion, sprayed on the trunks of standing infested trees in 1951, DDT and chlordane caused mortality of 76 to 78 per cent. of the beetle brood and were notably superior to other materials tested (106). In 1952, the concentration of active ingredient was increased to 80 pounds per 100 gallons of 20 per cent. oil-in-water emulsion. Aldrin, dieldrin, heptachlor, ethylene dibromide, and lindane produced mortality of over 90 per cent. of the broods in sprayed infested log sections on the ground. DDT produced an equivalent mortality, not in the immature brood, but in the new beetles as they emerged from the logs. Systemic insecticides yielded disappointing results, apparently due to inadequate translocation in infested standing trees (79).

Spraying trunks of standing infested trees, or spraying the trunks after felling, would have certain advantages over felling and burning in extensive control operations. Tests will be continued as opportunities permit.

Root Borer, *Hypomolyx* sp.

Wounds made by *Hypomolyx* larvae on the roots of white spruce trees in Manitoba and Saskatchewan serve as points of entry for root and butt rots. The weevils are most abundant in moist sites with a deep, friable duff layer; and are scarce or absent in dry sites, without a duff layer, or with grass sod cover (132, 135). An unusual concentration of *Hypomolyx* was recently discovered in dense stands of lodgepole pine in the Strachan area of Alberta. Roots of young to mature trees are attacked, and in one stand over 95 per cent. of the trees had been infested. Lodgepole pine is preferred to white spruce where the two species occur in the same stand. No serious ill effects of attack on lodgepole pine are yet apparent (110). Studies of the biology and host relationships of the weevil are continuing.

Seed and Cone Insects

Reforestation programs have been increasing in Canada, notably in Ontario and in British Columbia, with consequent increase in the demand for forest tree seed. Good cone crops are irregular in red pine, white spruce and Douglas fir, which are the species of greatest importance in reforestation programs. Insect attack seriously reduces seed yield in years of low or medium cone production, though it is less important in the years of heavy cone crops. Studies of the insects attacking cones and seeds of these tree species have been in progress, with the object of determining methods of preventing or reducing losses.

In Ontario, red pine cones are attacked by at least eight species of insects, of which the scolytid, *Conophthorus resinosae* Hopk., is the most important. It attacks the cones in the second year of their development, constructing breeding galleries along the cone axis. Attack is progressive during the season and 80 per cent. or more of the total cone crop in certain localities may be destroyed. Lepidopterous larvae also reduce seed yield, but less drastically than *Conophthorus*.

White spruce cones are attacked by a number of species of Lepidoptera and Diptera. In the Ottawa region the most destructive species are an anthomyiid fly, *Pegohylemyia* sp., and the seedworm, *Laspeyresia youngana* (Kearf.). The seedworm is the most destructive species at Indian Head, Saskatchewan.

Douglas fir cones in British Columbia are attacked by a number of caterpillars, cecidomyiids, and the seed chalcid *Megastigmus*.

Seeds of caragana, which is used extensively in shelterbelt plantings in the Prairie Region, are destroyed by a species of *Eurytoma*.

At the present time, control of cone and seed insects is impractical, since collecting is done rather generally from well-established stands of the various tree species. However, production costs can be reduced by avoiding areas with low crops and heavy insect infestations. There is a gradual development toward the establishment of "seed orchards," and when these are in operation the reduction of insect losses by cultural and chemical measures should be quite feasible.

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CYPRUS

WORK IN ECONOMIC ENTOMOLOGY DURING THE PERIOD 1948–1954*

During the period 1948–1954 the investigational work in entomology was concentrated on methods of chemical control of the cereal leaf miner, *Syringopais temperatella* Led. (Lepidoptera, Tineidae).

S. temperatella is the main pest of cereals in Cyprus, causing serious damage, especially to wheat and barley. The pest has been reported also from Israel, Syria, Turkey and Jordan. The insect aestivates during the summer in the first-instar larval stage in the soil at a depth of from approximately two to eight inches. The larvae break their aestivation after the first rains in November, come to the surface and mine into the leaves of the young wheat and barley plants. Several other plants are attacked to a lesser extent. The larvae frequently leave older leaves to attack younger leaves. Pupation occurs in April on or near the surface of the soil. The adult moths emerge eight to ten days later to mate and oviposit. About 50 eggs are deposited per female on dead leaves or on the ground. Incubation lasts for ten to twelve days and the young larvae enter, without feeding, their aestivation zone in the soil, where they spin cocoons.

Preliminary trials carried out during 1946–47 indicated that DDT and BHC could give a high degree of control of *S. temperatella*. Further trials conducted in 1947–48 in four different localities indicated that Agrocide 2 applied at the rate of 168 lb. per acre at time of sowing and ploughed in with the seed could produce a yield increase of about fifty per cent. Reduction of the rate of insecticide to 75 lb. per acre brought about a reduction in the degree of control. In 1948–49, different ways of applying Agrocide 2 at sowing time were compared. No significant difference was found between treatments, but the difference between treated and untreated plots was again significant. Agrocide 2 applied at the rate of 59 lb. per acre, costing £1 14*s*. 6*d*., gave (where the infestation was high) a yield increase worth £6 16*s*. 6*d*. per acre. DDT five per cent. dust applied at sowing time at the rate of 118 lb. per acre gave control similar to that obtained with Agrocide 2, but at much higher cost.

Treatments with BHC and DDT were also tried during the growing season as dusts and sprays, when the plants were four to six inches high. The dusts included five per cent. DDT and Agrocide 3, both used at the rate of 42 lb. per acre, and the sprays twenty per cent. DDT wettable powder and Wettable Agrocide, both used at a concentration of 0·25 per cent. at the rate of about 110 gallons of spray per acre. All these treatments gave increases in yield of grain up to forty per cent. or more, depending upon the severity of attack. No significant difference was found between the effects of the various materials. In 1948–49, five per cent. DDT dust applied to the growing crop at the rate of 42 lb. per acre gave an increase in yield valued at more than three times the cost of treatment. In 1949–50, three and a half per cent. and seven and a half per cent. BHC were tried at growing time at the rate of 42 lb. per acre with and without 2, 4–D at seven and a half per cent. No significant difference between the results obtained with the two strengths of BHC was found. A crop increase of up to two hundred and sixty-six per cent. over the untreated was recorded from the plots treated with BHC alone. 2, 4–D alone gave a crop increase of up to two hundred per cent., while BHC and 2, 4–D combined gave up to three hundred per cent. increase.

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* The work reported here was carried out by H. M. Morris, M.Sc., F.R.E.S., Government Entomologist (1927–1951) and Mr. Th. Shiakides, Assistant Entomologist.

Experiments carried out during 1950–51, 1951–52 and 1952–53 with sowing and growing-time treatments were discarded either because of very low infestation or favourable weather for crop growth in the spring which offset the injury caused by the insect during the winter.

From the above trials it was concluded that BHC, applied at the rate of 42 to 60 lb. per acre at sowing time or 42 lb. per acre during the growing season, offers the best method of economic protection of the crops from the attacks of *S. temperatella*. Treatments at time of sowing are simple to apply and inexpensive, but since there is no indication of how severe the infestation will be, the material may be wasted if the degree of attack is low. Treatments during the growing season do not present this disadvantage since they can be applied only when the infestation is high enough to warrant the expense of treatment. Such treatments, however, may be difficult to apply if weather conditions during February and March are unfavourable.

Further experiments with sowing- and growing-time treatments with the above and other insecticides are in progress.

A number of small-scale experiments was also carried out during the period 1948–1954 against the following pests :—*Ceratitis capitata* Wied., *Dacus oleae* Rossi, *Asphondylia gennadii* March., *Aphis gossypii* Glov., *Earias insulana* Boisd., *Pectinophora gossypiella* Saund., *Theresia ampelophaga* Bayle., *Vespa orientalis* F.

EAST AFRICA HIGH COMMISSION

FOREST ENTOMOLOGY

The present forest entomologist started work in January 1950 with the Kenya Forest Department, and in October 1951 transferred to the East African Agriculture and Forestry Research Organisation ; it will be convenient to consider the whole period.

The staff consists of one African ; however, Kenya deputed one European forester to help with field work and Uganda two African forest rangers who, after preliminary training in Kenya, performed most useful survey work in Uganda forests. Kenya filled the vacant post of forest entomologist in early 1953 (S. J. Curry).

At first there was no reference collection and very little information on forest insects. Under the heading " Survey of East African Forest Insects " a considerable and authoritatively identified collection has already been built up and for each species at least some biological information has been card-indexed and recorded. We are indebted to the Commonwealth Institute of Entomology for continuous assistance. A particular point has been made of maintaining a spirit collection of identified immature stages, and it is with pleasure that such material in the family Cerambycidae has been made available to Mr. E. A. J. Duffy to help in the production of his monograph on larvae of that family.

Particular attention is being given to the control of the Cerambycid, *Oemida gahani* Distant, a menace to Kenya's cypress plantations and also to structural wood in buildings. The species has recently been discovered in Tanganyika. A preliminary account was published in 1953*. Damage to seasoned timber by Bostrychidae and Lyctidae is very considerable in all three territories. An appreciation of the situation was made in 1950, and the question of implementing preventive measures has been under active consideration by the authorities concerned.

Serious loss in all three territories is due to ambrosia beetles (and studies are in progress), to the gall-forming Psyllid, *Phytolyma lata* Scott, on the valuable *Chlorophora excelsa* and to several species of borers in living trees.

In 1950 the Coccinellid, *Hyperaspis jocosa*, was imported from Hawaii in an attempt to control the *Orthezia insignis* blight so damaging to ornamental jacaranda trees. The beetles were reared in large numbers in Nairobi and released in a test area where, apparently, control appears to be successful. A stock was then handed over to the Senior Entomologist of the Agricultural Department for wider dispersal, with, it is understood, satisfactory results.

So far no serious defoliation by Lepidoptera has been recorded ; an outbreak, at first alarming, of *Acanthopsyche aethiops* Hamps. (Psychidae), resulting in almost complete defoliation of thirty acres of *Pinus radiata* in 1950, died out subsequently. The introduced weevil, *Gonipterus scutellatus* Gyll., which defoliates some species of *Eucalyptus* and not others is widely distributed ; control by the Mymarid egg-parasite, *Anaphoidea nitens*, is not efficient in some regions, probably owing to breaks in the even continuity of stages of the weevil. The planting of non-susceptible species best suited to a particular locality has been recommended.

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FIJI

(with references to other Western Pacific territories)

ECONOMIC ENTOMOLOGY, 1948–1954

By B. A. O'Connor

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During the period under review there has been only one entomologist on the staff of the Fiji Department of Agriculture. Until recently he acted in an advisory capacity to Western Pacific High Commission Territories, including the British Solomon Islands Protectorate, Tonga, the Gilbert and Ellice Islands and Pitcairn Island. In June 1952, Dr. J. S. Phillips was appointed to the British Solomon Islands for a period of one year, to work primarily on the problem of premature nutfall in coconuts, caused by the bug *Amblypelta cocophaga* China. At the end of his tour, Dr. Phillips did not seek re-appointment, and left the Protectorate in August. It is understood that his successor has been appointed.

The main entomological problems which have been dealt with during the past six years are as follows :—

The Rhinoceros Beetle, *Oryctes rhinoceros* L. (1, 2)

This insect was first discovered in Fiji in March 1953, near Suva. It had been established in Samoa for over forty years, and was first found in Vavau, Tonga, early in 1952. In Fiji a campaign of eradication was begun, financed by a tax on copra which it was estimated would yield £12,000 per month. The fund so raised is administered by a Board having as chairman the Director of Agriculture, with three members representing commercial and planting interests. A great deal of publicity was given to the pest, and the time-honoured control methods of destroying breeding places, collecting beetles, grubs, eggs and pupae, providing compost traps and instituting rigid quarantine measures were employed. Later, when the known infested area had increased considerably in extent, the goal of eradication was realised to be unlikely of attainment. Hence it was decided to make the objective of the campaign close control of *Oryctes* in the island of Viti Levu, and prevention of its spread to other islands of the Fiji Group. The labour force employed was reduced from 200 to 100, and has now risen again to 150. The known infested area is in the south-eastern corner of Viti Levu, extending about 30 miles in an east-west direction, mainly along the south coast, with isolated areas as much as 20 miles north of the main area. Feeding marks have been found 20 miles inland, and at isolated points further from the main area of infestation. Approximate totals of collections up to March 7th 1954, i.e. twelve months after the first discovery of the beetle in Fiji, are 275 adults, 90 pupae, 1600 larvae and 200 eggs. Considerable use is being made of compost traps consisting of pits 2 ft. 6 in. × 2 ft. 6 in. × 1 ft. 6 in. deep, filled with sawdust, plus 12 lb. of coconut meal, plus 1 lb. of BHC 50% dispersible powder (6·5% gamma isomer) in 8 gallons of water. Cage experiments showed this type of trap to be attractive and lethal to adults. Another control measure used is the placing in the axils of the four or five youngest fronds of coconut palms of a mixture of one part by volume of the BHC dispersible powder in 9 parts of sawdust. This is carried out as a routine whenever a palm is climbed for inspection. This technique gave a high mortality of beetles in the experimental cage, at least when the mixture was fresh. The original idea was provided by Mr. G. S. Dun, Senior Entomologist, Department of Agriculture, Papua, New Guinea, who obtained good results by using DDT powder in this way (3) on young oil palms. Further work needs to be done on the best formulation of BHC and the most economical dosage to give an adequate residual effect.

The South Pacific Commission has appointed two entomologists to work on the problem of *Oryctes rhinoceros*. One of these is stationed in Samoa and the other in India. A third member of the research team is to be a chemist, who will seek an effective synthetic lure for the beetle. Fiji expedited the initiation of this research project by guaranteeing the full cost for the first year.

Amblypelta cocophaga **China in the British Solomon Islands** (4, 5, 6, 7, 8)

During a visit to the Solomon Islands in 1948, Leach and O'Connor observed that the ant, *Oecophylla smaragdina subnitida* Emery, had recovered much ground in coconut plantations near Honiara, Guadalcanal, from which it was being gradually driven out before the war. In consequence, palms which had been out of production for years were bearing very heavy crops, as *Oecophylla* controlled the bug, *Amblypelta*, whose feeding causes heavy premature nutfall. Leach and O'Connor concluded that the growth of certain plants, mainly creepers, which covered the plantation floor, and provided a bridge for *Oecophylla* from trunk to ground had enabled the beneficial ant to overcome the harmful species *Pheidole megacephala* Fabr. When O'Connor again visited the Solomon Islands in 1950, almost complete recovery from premature nutfall had occurred on the plantations, *Oecophylla* having almost entirely overcome *Pheidole*.

Dr. J. S. Phillips, who subsequently worked on the problem from June 1952 until August 1953, does not accept the " creeper " theory, which he considers to be invalidated by the situation on other plantations on Guadalcanal. He has put forward the theory that aerial spraying with oil solutions of DDT by the U.S. Forces explains the recovery from premature nutfall and the changed *Amblypelta* and ant situation on the plantations near Honiara. This theory is not accepted by Leach and O'Connor.

" Rice Yellows " (9)

Work on this disease of rice has shown that it is due to feeding by the Delphacid leafhopper, *Sogata furcifera kolophon* Kirkaldy. It appears unlikely that a pathogen or a toxic secretion is involved. Apparently feeding by great concentrations of leafhoppers causes symptoms of disease by interfering with the nutrition of the plant. DDT sprays are recommended for control. There is some evidence that the leafhopper, a native insect which adapted itself to the rice plant, is being gradually brought under control by native species of Mirid bugs, primarily *Cyotorhinus riveti* Cheesman and *Cyotorhinus vitiensis* Usinger, which are predators on the eggs of *Sogata*.

The Coconut Stick Insect, *Graeffea crouani* **Le Guill.**

Localised outbreaks of this Phasmid periodically cause severe damage to restricted areas of coconuts, even to the extent of killing a proportion of the infested palms. Control by applying sticky bands to palm trunks has been unsatisfactory, and only 50% mortality has been obtained by power-dusting with BHC, largely because of practically continuous wind in the area treated, and insufficient power of the dusting machine. Most eggs of the Phasmid fall to the ground, but it has been found that some lodge in the axils of the palm-leaves, and nymphs hatch from these eggs. This could explain the failure of sticky bands, if the numbers of eggs which lodge in the crown of the palms are sufficiently high. Recently a Eupelmid parasite of the eggs has been found, which appears to be commonly distributed.

The Banana Scab Moth, *Nacoleia octasema* Meyr. (10, 11)

Experiments with various types of insecticidal dust showed that 2% DDT dust was the cheapest and most effective material for dusting of the young banana bunch to control Scab Moth. DDT has therefore replaced pyrethrum as the standard treatment in Fiji. Dusting alone does not guarantee the production of completely scab-free bananas. However, it was found that if the bunch and the upper surface of the four or five youngest leaves were sprayed with one part by volume of 20% DDT emulsion in 100 parts of water when the erect bunch has emerged to about half the height which it will finally attain, and the hands were later dusted with DDT powder, completely clean bunches were produced.

Miscellaneous

During the last year, a campaign against the termite *Coptotermes acinaciformis* Frogg. has been conducted at Suva wharf. This destructive subterranean termite has been present in the wharf timbers for many years, but as far as is known has not spread elsewhere. Dusting of the galleries with paris green appears to have produced good results.

Scolytid beetles boring in and killing mahogany and cedar seedlings were controlled by spraying with BHC.

A survey of the insect pests of Tonga has been made, and recommendations have been given for control of various pests (12).

Biological Control of Insects and Weeds

A paper on this subject was prepared for the 7th Pacific Science Congress, and later published in the Fiji Agricultural Journal (13). In 1948 the establishment of the Ichneumonid parasite, *Cremastus flavoorbitalis* Cam., was recorded for the first time since its introduction from Hawaii by Mr. H. W. Simmonds, O.B.E., in 1935. It was bred from the rice leafroller, *Marasmia venilialis* Wlk., and since then it appears to have brought about excellent control of the leafroller. Lever (14) recorded parasitism of *M. venilialis* by an Ichneumonid (? *Cremastus*) in 1946. This was probably *C. flavoorbitalis*.

In December 1949, one hundred puparia of the Tachinid fly, *Trichopoda pennipes* F., were received from Florida, U.S.A., where they had been collected and forwarded by Dr. F. J. Simmonds. The fly was bred through several generations in Fiji, and 800 puparia were taken to the Solomon Islands, where a liberation of 205 mated females was made on the island of Malaita in May. It was hoped that *T. pennipes* might exert some control on the Coreid bug, *Amblypelta cocophaga* China, which causes severe premature nutfall of coconuts. So far there is no evidence of establishment on Pentatomid or Coreid bugs in the Solomons, or in Fiji, where liberations were also made (15).

In April 1950, consignments of two species of parasites were imported from Hawaii for control of the Rice Army-worm, *Pseudaletia separata* Walker. Eleven hundred cocoons of *Apanteles marginiventris* Cress. and one hundred puparia of *Eucelatoria armigera* Coq. were received. Most of the emerging *Apanteles* were released in the field, and some were bred successfully on *P. separata* in the insectary. Though attacked by several local species of secondary parasites, *A. marginiventris* became established in great numbers throughout the island of Viti Levu in a very short time. Apparently it has suppressed the army-worm, of which there have been no serious outbreaks since. As far as is known, *E. armigera* has not established itself. Only a few of this species were liberated.

In March and April 1951, consignments of fruit-fly parasites, *Opius* spp., were received from Hawaii. These species attack *Dacus dorsalis* in Hawaii, and it was desired to try them against the Fijian species, *Dacus passiflorae* Frogg. and *D. xanthodes* Broun. If they became established, they would be an insurance against damage liable to be done by a possible introduction of *D. dorsalis*. The parasites arrived just before the Government Entomologist proceeded on leave, and attempts to breed them on local fruit-flies, which were carried out during his absence, failed. Liberations made comprised 5000 male and 2000 female *O. vandenboschi* Full., 270 male and 380 female *O. oophilus* Full., and a very few *O. longicaudatus* Ashm. and *O. incisi* Silv. None of these is known to have become established. In February and March 1954, further colonies of *O. oophilus* and *O. longicaudatus* (3 sub-species) were received.

In February 1951 a visit was made to Queensland to pick up a colony of *Euaresta aequalis* Loew, a seed-fly which breeds on Noogoora Burr (*Xanthium italicum*) (16). One thousand male and one thousand female flies were liberated at Naduri, in the valley of the Sigatoka river. Dissection of many thousands of burrs during the last three years has failed to reveal the presence of the seed-fly.

Towards the end of 1952, a visit was made to Rabaul, New Britain, in the Territory of Papua and New Guinea, with the primary purpose of introducing to Fiji the Tachinid parasite, *Bactromyia fransseni* Baranov, which includes the Banana Scab Moth, *Nacoleia octasema* Meyr., among its hosts. Mating of this species could not be induced in captivity, and at the time of the visit the fly was scarce in the field, so that no introduction to Fiji was made. Later Mr. G. S. Dun, Senior Entomologist, Territory of Papua-New Guinea, sent a few of the parasites, which were liberated in the field.

A Bethylid parasite of *N. octasema* was found in New Britain, and this species, *Geniozus triangulifer* Kieff., was brought back to Fiji. One liberation of 50 females and 20 males was made, but within a few generations the insectary stock died out, due to a low survival rate of the parasite larvae and the production of a disproportionate number of males. In Rabaul, breeding of this species had been simple.

Two parasites of *Agonexena pyrogramma* Meyr., whose larvae feed on coconut leaflets, were found in New Britain, namely a Dipteron whose larvae emerge from those of its host and fall to the ground, and *Apanteles stantoni* Ashmead. It is hoped that these may be introduced to Fiji at a later date for use against the local pest species, *Agonoxena arganla* Meyr.

A sum of £1,000 was placed at the disposal of the Commonwealth Institute of Biological Control for preliminary investigations in Trinidad into possible control of some of our local weed species by insects. An amount of $2,000 was also contributed to a project for biological control of *Lantana* which was originated by the Board of Commissioners of Agriculture and Forestry in Hawaii. Several promising insects have been found in Mexico by the latter organisation, and after starvation tests and breeding up of stocks in Hawaii, approved species will be imported to Fiji. The first of these, the Pyralid, *Blepharomastix acutangulalis*, will be received here shortly.

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GOLD COAST

REVIEW OF ENTOMOLOGICAL WORK OF THE DEPARTMENT OF AGRICULTURE, 1949–1953

Although there are several entomologists in the Gold Coast, some at the West African Cacao Research Institute, others engaged in tsetse research and still others investigating *Simulium* and other insects of medical importance, there has been only one entomologist responsible for work on plant pests and storage pests. There has been some increase in subordinate staff, but it was not until December 1953, that a second entomologist, to be concerned mainly with storage problems, was appointed to the Department of Agriculture. This appointment will result in a considerable expansion of food-storage investigations, which have, perforce, been somewhat neglected.

The status of cacao as the Gold Coast's biggest source of revenue, and the serious consequences that would follow a failure of this crop, have tended to obscure the fact that the Gold Coast, like most other tropical territories, is still dominated by peasant food-farming, which in some areas is barely at subsistence level, and with a fair quota of pests. The absence of any important cash crop apart from cacao has led to a concentration of work on food crops, the most important of which are the cereals, maize, sorghum, millet and rice. The main pests of these crops are almost all Lepidopterous stem-borers, the most notable exception being the sorghum midge, *Contarinia sorghicola* Coq.

Over 20 stem-borers have been reared from cereals and various grasses, several being new genera and species; some of these, of the family Agrotidae, have already been described (1). Several more await description. Progress has been made with the separation of the various species in the larval and pupal stages, but there are still several species that cannot as yet be satisfactorily separated other than as adults.

Pests of Maize

At least seven borers are known to attack maize, the most important being *Sesamia botanephaga* Tams & Bowden, *S. calamistis* Hampson, *Busseola fusca* (Fuller) and *Eldana saccharina* Wlk. Between them these species, and in particular *S. botanephaga* and *B. fusca*, are the main limiting factors to a successful second crop of maize over most of the forest area of the country. Crop loss is conservatively estimated at 15,000 tons per annum, about 10% of the present total crop, apart from an unknown quantity lost through reluctance to plant because of borer attack.

Some time has been spent in working out a sampling method for large-scale surveys. Such a method must be reasonably accurate, yet simple and speedy, and be able to record both the extent and intensity of attack. A method based upon 100 plants across a diagonal was rejected because of difficulty in navigating through tall growing crops; a second, involving 100 plants taken from 10 randomly selected points within a farm or field was discarded because of bias towards attacked plants. The system now in use is based on a sample of 100 plants per acre taken from 4 fixed points within the field or farm, with a subsample of 25 plants to assess numbers of larvae. The results have not yet been subjected to analysis, but would appear to be reasonably reliable except at infestations of 5% or less, when the error becomes considerable. This at present is a relatively unimportant disadvantage since the main interest centres in defining areas of heavier infestations, for extension campaigns. It is clear, however, that the method will require some modification for areas of light infestation.

Infestation is worst in late-crop maize planted with the minor rains. Infestations up to 100% have been recorded with up to an average of 5 larvae per attacked stem. At this intensity, loss of crop is almost complete. In normal infestations with 100 or less larvae per 100 stems, yield is 10–12% less in attacked plants. Attack is severe in the late crop irrespective of planting dates. The following table illustrates the damage that can be inflicted:—

Planted	% Infestation	Nos. larvae per 100 plants	Estimated crop loss due to borers
Sept. 5th–6th	61	238	45–50%
„ 7th–8th	53	281	45–50%
„ 15th	78	168	25–30%
Oct. 6th	50	123	15–20%

Although it is evident that crop-loss decreases with the later plantings, 20–30% is still sufficiently serious to deter many farmers; further, because of the relatively short period of the minor rains, later plantings are increasingly poor risks.

Of the four species listed earlier, *S. botanephaga* has been most intensively investigated.

S. botanephaga **Tams & Bowden**

This is the dominant borer over most of the forest zone, but in the marginal dry deciduous forest it is co-dominant with *B. fusca.* It has been reared from maize, rice, cultivated sorghum, sugar-cane and 10 grasses, most important of which are *Pennisetum purpureum* (elephant grass), *Sorghum arundinaceum*, *Rottboellia exaltata* and *Setaria chevalieri.* Infestation of maize commences when the plants are 5″–6″ high, and will continue until the plants are 18″ or so high; females are capable of depositing up to about 350 eggs. It has been found that the number of eggs per female is correlated with final larval size and the size of the female. It has also been found that development is quicker, larvae have fewer moults and percentage survival is higher in maize than in *S. arundinaceum*, young *P. purpureum*, old *P. purpureum*, *R. exaltata* and *S. chevalieri*, which follow maize in that order. This work is being continued together with host-plant analysis in an attempt to discover possible sources of resistance.

No diapause is known to occur in *S. botanephaga*; carry-over is by populations in grass hosts and, to a much smaller extent, in crop débris; it is recommended that crop débris be destroyed as a matter of general farm sanitation, but except in areas in which *B. fusca* occurs this can exert little control.

The most effective control method is a simple dusting routine employing a 5% DDT dust. Yield increases are 40–50%. Two applications are recommended, at 14 and 28 days from date of planting; an extension campaign using this technique is now in progress.

S. calamistis **Hmps.**

This species is found mainly in the Southern Savannah area of the country. Infestations in this region are rarely above 20%. The control measures used against *S. botanephaga* are applicable to *S. calamistis.*

Busseola fusca **(Full.)**

This borer is found throughout the Savannah areas, extending into the dry deciduous forest where it overlaps *S. botanephaga.* It is thought to be extending its range as a consequence of progressive deforestation. Alternate hosts in maize areas are *S. arundinaceum* and *R. exaltata*; it has not been found in *P. purpureum.* Carry-over is through grass populations, but residual populations in crop débris are also important, and such débris must therefore be destroyed. For areas in which this species occurs a third dusting with 5% DDT at about 8 weeks from planting is recommended to control the second generation in maize; a third dusting is unnecessary elsewhere since there is at most only a very slight reinfestation by *Sesamia* spp.

Eldana saccharina **Wlk.**

Important chiefly as an ear-worm, although the larvae will bore into the stems. The eggs are laid on or near the silk, occasionally on the leaves. Carry-over is largely by larvae in crop débris, particularly in cobs; the larvae are rarely found in grasses, certainly not in sufficient quantity to constitute an important source of infestation. Recent work shows that pods of trees of the genus *Parkia* may be important reservoirs of this species and also of another ear-worm, *Mussidia nigrivenella*. 5% DDT dust applied to the silks has so far given unsatisfactory results; work on insecticidal control is continuing.

PESTS OF MILLET

Two Lepidoptera cause considerable, and at times severe, loss in this crop, the staple food of large numbers of people in the Northern Territories.

Coniesta ignefusalis **Hampson**

This Pyralid, previously known as *Proceras ignefusalis*, causes an unknown loss but which is thought to be not less than 5% and sometimes considerably more. The sampling method used to assess infestation rates is similar to that in use for maize borers, except that the total number of stems in 100 stands is used; this is necessary because of the profuse tillering of millet. Attack is invariably worst on late millet, but varies considerably from year to year and from district to district.

It is estimated that at a density of 3 larvae per stem, about the normal, attacked stems produce 54% less grain than sound stems. In millet however not all attacked stems would normally head, and until the ratio within the attacked portion of the crop between heading and abortive tillers can be estimated it is not possible to calculate overall losses.

Attack would appear to be determined, at least in part, by the rainfall in July; a dry month retards the plants and keeps them in a suitable stage for oviposition for a much longer period than in a good rainfall month. Carry-over is by diapause larvae found in trash and stools left in the field; the majority of the larvae are found in the stools, within the main roots 2″-4″ below ground level. Ploughing out and burning is the obvious way of disposing of this crop residue, but other methods of disposal which do not involve trash destruction are being investigated, since a large part of the most severely affected areas suffer from severe soil exhaustion.

Heliothis armigera **Hb.**

The millet ear-worm is most prevalent in early millet when some 15–20% of the heads may show the characteristic spiral feeding tracks of the larvae. Loss of grain is probably quite small in most cases, but the larvae will cause heads to snap off. There is only one main generation on millet, the larvae pupating in the soil. The fate of these pupae is not known, but, in view of the relative absence of damage to late millet, either a diapause intervenes or the emerging adults oviposit on other host-plants.

PESTS OF RICE

To date, relatively little work has been done on this crop, although several species of borers have been found. Potentially the most important is a species of *Chilotraea* probably *africana* Auriv. found in the Northern Territories. Preliminary observations show that, as would be expected, poor tillering varieties suffer most loss; and further, that timing and duration of flooding may have considerable effect, since the larvae cannot, apparently, make use of water movement but are drowned within the stem.

Rice within the forest area is attacked occasionally by *S. botanephaga*, and also by a species provisionally identified as *Ampycodes pallidicosta* Hampson (*Rhinaphe vectiferella* Rag). Even so, it is not thought that damage caused by this insect is economically significant; the fact that *A. pallidicosta* is apparently restricted to rice, and the scattered nature of rice cultivation within the forest, probably account for its unimportant status.

PESTS OF SORGHUM

The major pests of sorghum are *Busseola fusca*, *Sesamia poephaga* Tams & Bowden and *Contarinia sorghicola* Coq., while *Eldana saccharina* and *Coniesta ignefusalis* occur sporadically.

Stem-borers

Stem-borer attack is not usually considered of great importance in the Gold Coast, but late crops can be, and often are, completely wiped out. Native farming practice is such that the bulk of the crop is harvested before much damage can be done, but some inconvenience has been caused to Departmental programmes through borer attack in variety trials.

It would appear that one of the main factors limiting damage is stem thickness, particularly in the peduncle, as distinct from stem strength. A thin peduncle is usually completely hollowed out and the entire head is blind, even if it does not break, whereas a good thick peduncle allows the larva room for manoeuvre and still produces some sort of a crop.

Where necessary, infestation in young sorghum can be controlled as for maize borers. Reinfestation occurs when native varieties have grown beyond the reach of the simple dusting equipment used, but the dwarf varieties can easily be dusted. *B. fusca* has been reared from several grass species within the sorghum belt, but the most important reservoir of infestation is the crop residue, in which stems and stools appear equally important. The comments made with regard to disposal of millet residues apply equally well here, but are complicated by the fact that sorghum stems are frequently used as building material. This obviously is a considerable obstacle to the introduction of dwarf varieties, but " semi-dwarf " or " semi-talls " would possibly be favourably received.

Sorghum Midge, *Contarinia sorghicola* Coq.

This pest, since it was first recorded in 1951, has been found throughout the Northern Savannah area of the Gold Coast. A midge morphologically identical with *C. sorghicola* has recently been recovered from the grass *Sorghum arundinaceum* from a locality within the forest zone; preliminary cross infestation experiments indicate that this midge is in fact *S. sorghicola*.

The life history of the midge is basically very similar to that in the Sudan and America. Up to 5 fully matured larvae have been found in a single grain, although such high densities are mainly the result of shortage of grain in a suitable state for oviposition. Some attention has been paid to the time of oviposition in relation to emergence of the head from the sheath. It has been found that, under conditions of shortage of oviposition sites, oviposition will occur before anthesis, but only when the glumes begin opening, 36–48 hours before anthesis. In an East African sorghum grown as " Kavirondo sorghum " oviposition occurred on the first grains emerging from the sheath, but in this variety it was obviously due to the fact that the anthers burst immediately the grains emerged from the sheath; none of the local Gold Coast sorghums have this habit, which possibly explains the discrepancy between Gold Coast observations and those recently recorded from Uganda.

A programme of control is based on the very marked degree of resistance shown by a group of native varieties typified by Nunaba, belonging to the *Sorghum marginatum* group. These varieties, restricted to the north-east of the Gold Coast, owe their resistance to the fact that the glumes do not open at anthesis (2). Counts have shown that Nunaba has 5% or less midge attack compared with 30–80% in open-flowering varieties flowering at the same time. Crosses involving Nunaba are less resistant than Nunaba itself, but nevertheless show 10–20% less than other open-flowering varieties. There is also evidence that compact-headed types are less severely affected than lax-headed varieties, due presumably to inability of the midge to oviposit beyond the outer grains. The compact types however have the disadvantage that they are more heavily infested with various bugs, and are more susceptible to fungal attack. As an immediate remedy, early planting, so far as practicable, is recommended. Midge attack is related to time of flowering, as shown by the following table for one station:—

Date of flowering	% Attack
15th October	0
29th ,,	1·0
12th November	5·5
26th ,,	14·0
8th December	36·5
15th ,,	44·0
22nd ,,	36·0
7th January	51·0
21st ,,	32·0
4th February	22·0

A schedule of last flowering dates, ranging from mid-September to early November, according to locality, has been drawn up for sorghum-growing areas.

Cultural practices designed to reduce the spread of flowering, which may extend over 8 weeks, are being investigated.

A preliminary insecticide experiment has shown that DDT has promise. Results were, in percentages of undamaged and midge grains:—

	1% DDT	0·2% gamma BHC	Control
Undamaged	52·0%	25%	9%
Midge	14·5%	22%	31%

A feature of considerable interest in this experiment was that the percentage of undamaged grain was increased over what had been expected from midge control alone. This was probably due to control of various bugs (*Dysdercus* spp., *Mirperus* spp., *Riptortus* sp. and others) that swarm over sorghum in the milk stage.

PESTS OF YAMS

Yam Scale

A Coccid, tentatively identified as *Aspidiotus hartii*, commonly occurs on yams, mainly in store, to a lesser extent in the field. Populations build up rapidly during the dry season, and the farmers complain that germination is reduced although there is no evidence to support this. A preliminary experiment involving dips of BHC, aldrin and dieldrin and nicotine sulphate gave inconclusive results, largely owing to great variability of scale populations and the lack of an adequate sampling method.

Crioceris livida **(Dalm.)**

Adults and larvae of this Chrysomelid cause defoliation, sometimes severe, soon after the onset of the rains. The insect is easily controlled by a 0·4% BHC spray.

Ptyelus grossus **F.**

A severe infestation of this Cercopid was recorded on yams in 1949 causing considerable yellowing and distortion of the vines.

The area affected was small, and control was achieved by hand-collection of the insects, rendered relatively easy because of the markedly gregarious habits of both nymphs and adults.

PESTS OF CITRUS

Fruit-piercing Moths

Attempts to rear laboratory colonies of two major fruit-piercers, *Othreis divitiosa* Walk. and *Achaea lienardi* Boisd. to provide material for testing various systemics and other insecticides, have not proved successful; although *A. lienardi* produced two generations, third-generation eggs all failed to hatch. Work is continuing in this direction; better results are looked for by the addition of some wild stock to each laboratory generation.

Prompt harvesting, still a somewhat unattainable ideal, remains the recommended " control " method.

Citrus Shoot Borer *Cercyonia citri* Bryant

This Halticid causes considerable damage to nursery citrus, of all types. The adults cause considerable defoliation but most damage results from the boring of the larvae in the terminal shoots. This insect has proved extremely difficult to rear under laboratory conditions, and its life cycle is not known in any detail. A control experiment gave rather inconclusive results, but showed that BHC and DDT were promising, although repeated spraying at frequent intervals would appear to be necessary, particularly at periods of flush.

Black Citrus Aphid, *Aphis citricidus* (Kirk)

This Aphid is of importance on two counts—as a pest of nursery citrus and as the vector of tristeza or " die-back " of limes and other citrus. A new investigation of the relationship of this Aphid to the disease has been started; there is evidence that two or more virus strains are involved, one of which causes a distinct " little leaf " symptom. Previous work (3) showed that the mealybug, *Ferrisia virgata* (Cockerell), also transmitted the die-back virus to limes, but it is not certain that the virus transmitted by the mealybug is the same as that transmitted by *A. citricidus*; this is being investigated.

Control experiments show BHC and aldrin sprays to be more effective than either dieldrin or toxaphene. Further experiments with BHC and aldrin are in progress.

Citrus Swallow-tail, *Papilio demodocus* Esper

The larvae of this Papilionid can cause considerable defoliation of citrus after planting out. Damage is most severe during and shortly after the dry season. The larvae are controlled by a 1% DDT spray at fortnightly intervals.

MISCELLANEOUS PESTS

Leaf-nesting Ants, *Oecophylla smaragdina*, and *O. longinoda* (Latr.)

Some observations and experiments on the biology and control of these ants have been carried out. Usually considered to be subspecies at most, there are some differences in their ecology, notably that *longinoda* is invariably the more aggressive of the two; is usually found in smaller colonies; is not found in savannah conditions, whereas *O. smaragdina* occurs in the inland savannah immediately north of the forest belt and is also common in the coastal savannah; finally, neither winged males nor winged females of *O. longinoda* appear to be attracted to light, whereas those of *O. smaragdina* are commonly so.

The object of control measures has been to rid citrus and coffee, especially the latter, of these ants during harvesting. *O. smaragdina* is so abundant as to render harvesting at best exceedingly uncomfortable and at worst almost impossible. In conjunction with poor cultural practices these ants are responsible for the present prevalence of coffee berry borer. Of the insecticides used, DDT at 4% spray prevented reinfestation for 3–4 weeks, whereas BHC, aldrin and dieldrin sprays all prevented reinfestation for 3 months; further work with these insecticides is in progress.

Since it had been found that ant activity, as measured by the number moving past a given point in one-minute periods, was greatest at temperatures over 80° F, the sprays were applied from 10.30 a.m. onwards when temperatures will have risen above 80°.

Army Worm, *Laphygma exempta* Walk.

Country-wide outbreaks of this species occurred in 1951 and to a lesser extent in 1952. In both years outbreaks were due to the sudden onset of the rains following a long and severe dry season. Considerable damage was caused to cereal crops, particularly maize, while several golf courses suffered severely; most of the damage in both years was caused by the second outbreak generation; natural causes, especially what appeared to be a virus disease, decimated subsequent generations.

Tests of various insecticides showed that parathion gave 100% mortality; BHC dusts and sprays were somewhat less effective, averaging 75–80% mortality, but were recommended for general use. An attempt to control the larvae in maize using a low-volume sprayer with a 0·4% BHC spray was only partially successful, due to poor spray cover, although the same method was very successful in dealing with outbreaks in lawn grasses.

Flea Beetles, *Podagrica* spp.

P. uniformis Jac, and to lesser extent *P. sjostedti* Jac cause considerable damage to a variety of crops, notably okro (*Hibiscus esculentus*), egg plant (*Solanum melongena*) rama (*Hibiscus cannabinus*) and *Urena lobata*. A control experiment was laid down on okro using sprays of DDT and BHC, both at 0·4% and 0·2%. Of these, DDT at 0·4% was easily the best, and has been recommended for control where necessary, applied at 10-day intervals.

Harvester Ants, *Messor* sp.

These ants are a considerable nuisance in the Northern Territories. Several attempts to establish grass leys (mainly *Pennisetum polystachyon*) have failed to some degree because of seed removal. The ants also frequently remove grain from millet heads. Aldrin and dieldrin applied to the nests have both shown promise, and are being tested further.

Variegated Grasshopper, *Zonocerus variegatus* L.

This handsome insect is frequently a dry-season pest of young tree crops. It has been recorded as defoliating citrus, coffee and cassava. 1% γ BHC spray has successfully controlled outbreaks on citrus and coffee. It is also recommended that grasses such as elephant grass be kept to a minimum around farms.

GRAIN STORAGE ENTOMOLOGY

Little original work has been carried out. It has been found that cobs of maize damaged by birds and rodents are significantly more heavily infested in the field by *Calandra* than undamaged cobs; there is evidence that destruction of the silk by *Mussidia*, *Eldana* and other ear-worms also predisposes cobs to *Calandra* attack.

It has been demonstrated that fumigation of bag stores of maize with an ethylene dichloride/carbon tetrachloride mixture can be a practical proposition, requiring only the simplest equipment. It is hoped that further investigations will establish this as a routine measure of protection for large grain-stores. An experimental underground storage pit is being constructed, and should be for main-crop maize in July.

The recent appointment of a grain storage entomologist has enabled a much more extensive programme to be started; some of the more important items are:—

(1) Field biology of *Calandra oryzae*.

(2) Biology of *Sitotroga cerealella*.

(3) Biology of *Gnathocerus cornutus* and its association with *Tribolium* spp.

(4) Insect infestation of stored cocoa.

OTHER WORK

The Division of Entomology is a useful source of various veterinary requirements, such as nicotine sulphate, carbon tetrachloride etc. and full use is made of it by agricultural officers. Several cattle have been treated with BHC washes for mange, with excellent results.

Imported European breeds of fowls have suffered severely at some stations from attack by biting flies. Investigation showed that *Stomoxys calcitrans* was mainly responsible, although *S. brunnilinea* also occurred; adults of both species settle on the wattles and combs, causing swelling and blackening. Various DDT and BHC washes were tried; the best was found to be a BHC wettable powder, which when painted on to the affected parts afforded relief for up to 7 days. This treatment is now regularly applied.

Other minor investigations have dealt with Dermestids in dried fish and eradication of *Argas persicus* Oken, the fowl tick; on one occasion enormous numbers of this tick were the cause of severe anaemia in several farm labourers. An investigation into the breeding places of Tabanidae in and around various Agriculture Stations has also been carried on, and is still in progress.

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WEST AFRICAN CACAO RESEARCH INSTITUTE, TAFO, GOLD COAST

The entomological work of the Institute has been devoted to the investigation of cacao pests, particularly the Mirids, *Sahlbergella singularis* Hagl. and *Distantiella theobroma* (Dist.), and the mealybug vectors of swollen shoot disease.

Mirid Pests

Ecology

Routine population studies continued throughout the period under review and have shown that the population of the two major species remains at a low level from March to July, gradually rises to a peak between December and February and then falls sharply. The general trend of the population is similar each year but the magnitude of the peak varies from year to year. More detailed work on the population trend is continuing with the object of establishing a relationship between environmental factors (including climatic factors, fruiting of the host-plant and inter-specific relationships) and the month to month variation and variations in the annual maxima.

Field studies concluded in 1950 showed that Mirid attack occurred principally where the cacao canopy was discontinuous as a result of mechanical damage caused by fallen shade trees, by the death of trees from disease or other adverse conditions, or in consequence of the depressing effect of certain conditions of overhead shade. Dense overhead shade was found to induce etiolation of the cacao with a consequent delay in the formation of a continuous canopy and thus to be a factor inducing Mirid attack. Sparse overhead shade also retarded the formation and prejudiced the maintenance of a continuous canopy by exposing the cacao to sunlight.

Anatomy and physiology

The anatomy and physiology of the digestive system of *Sahlbergella* and *Distantiella* were investigated in some detail. It seems probable that saliva is injected under considerable pressure into plant tissue on which the insects feed and fills the intercellular spaces for some distance around the feeding puncture; the effect of the high acidity resulting and the action of esterases, kill the surrounding plant cells, whose walls become permeable and whose contents are leached out.

Control

Chemical control.—The control of Mirids on young cacao is a particularly important problem since young seedling trees are particularly susceptible to attack and the establishment or re-establishment of cacao is frequently impossible without some method of protection. A successful method was evolved which consists of painting the branch unions, which are the resting places of the Mirids during the day, with a 2·5 per cent. DDT emulsion; this is performed three times a year.

Work is proceeding to protect older trees in a similar manner, using a modified pressure sprayer to deposit insecticide in those resting sites which are out of reach.

Mirid attack on mature cacao has been successfully controlled by the use of DDT dusts from a small power duster carried on a labourer's back. Frequent application of dust in this way has had no adverse effect on pollination.

Numerous trials of insecticidal smokes have been made but without success.

It has been found that trees severely damaged by Mirids can be protected against further attack by the use of insecticides as described above, but the trees remain misshapen and unthrifty.

Biological control.—Earlier work had suggested that the presence of the ants, *Oecophylla longinoda* (Latr.) and *Macromischoides aculeatus* Nar., protected cacao trees from attack by Mirids; this has since been found not to be the case and that the ants merely seek out healthy trees on which to establish themselves after a neighbouring area has been seriously damaged by Mirids.

Cultural control.—Trees which have been seriously damaged by Mirids and which, as a result, have become unthrifty and misshapen, can be regenerated by coppicing. Of the leading shoots which develop from the coppiced stump, one is preserved and is protected from Mirid attack by treatment with DDT. Trees regenerated in this manner have come into bearing within three years and this represents a marked saving of time as compared with replanting from seed.

Vectors of Cacao Virus

It will be appreciated that the Pseudococcidae of cacao are of economic importance solely as disease vectors and not because of any direct damage resulting from their feeding activities. Theoretically it should be possible to reduce the rate of spread of virus disease either by eliminating the sources of infection or by eliminating the vectors; while the former method alone has been found practicable in the case of nearly all virus diseases of tree crops, the possibility of controlling swollen shoot disease of cacao by vector control has been investigated in considerable detail. In addition the details of the life-history and mode of life of the vectors have been studied in order to ensure that the methods adopted for the destruction of diseased trees are as efficient as possible.

Ecology

Seventeen species of Pseudococcidae are associated with cacao in the field, of which thirteen are known to be capable of transmitting swollen shoot disease; vectors have not been found in any other insect group. These insects are not particularly numerous and have no significance as direct pests of cacao; the number of insects found on a single cacao tree is usually of the order of a hundred. There appears to be no relation between the magnitude of the mealybug population and the rate of spread of swollen shoot disease, although mealybug populations are usually smaller in areas devastated by virus than in areas where the disease is actively spreading.

In the Gold Coast the most abundant vector is *Pseudococcus njalensis* Laing, which is one hundred times as common as the second vector, *Planococcus citri* (Risso); the other vectors are relatively rare. Ant attendants of the mealybugs are of importance and *P. njalensis* is almost invariably attended in the field by Crematogasterine ants which build protective ' tents ' over mealybug colonies. Mealybug populations are influenced directly or indirectly by seventy-five species of ants, sixteen species of Hymenopterous parasites, three predatory beetles, one predatory Dipteran and three Arachnids. There are about 6–8 generations of mealybugs in the course of the year and they are present at all seasons; there is some evidence that the insects are more numerous in the dry than in the wet season.

Six vector species have been shown to be capable of being transported by wind and of establishing themselves on cacao after distribution in this manner. Wind distribution has been found to occur most commonly with *P. citri* and *Ferrisiana virgata* Ckll. and particularly in the dry season; dispersal by ants also occurs and the insects also spread as a result of their own locomotion. The phenomena of dispersal are being studied with the aid of radio-active tracers and techniques have been developed for obtaining radio-active trees whereby the insects can be ' labelled ' at their feeding sites.

The behaviour of mealybugs on trees which have been cut out in virus control operations has been studied in detail, particularly by the use of insects labelled with tracer levels of P^{32}. It has been found that movement of the insects from the piles of wood of the trees cut out is negligible.

The population density of *P. njalensis* is very variable and varies from six thousand to two hundred thousand insects per acre. The density variation is largely due to varying ant associations; this problem of ant-mealybug association also is being studied with the aid of radio-active tracers.

Control

Chemical control.—Numerous insecticidal sprays and dusts have been tested for the control of mealybugs on cacao and, while many have produced high mortalities, especially nicotine and parathion, sufficient vectors survive the treatment to render the operations ineffective as a practical means of arresting the spread of swollen shoot disease. The difficulties of insecticidal control are increased by the presence of tents over the colonies of *P. njalensis* but even in the absence of tents the insects are difficult to kill unless an efficient wetting agent is used with the spray.

The effect of systemic insecticides applied to the cacao tree has been studied since 1948. A ' screening ' technique has been developed for comparison of different preparations and at an early stage of these studies it was found that ' Dimefox ' (*bis* dimethylamino-fluorophosphine oxide) was absorbed in quantities toxic to mealybugs when applied to the soil in which a cacao plant was growing. Since 1950 intensive studies of the use of Dimefox have been conducted in association with Messrs. Pest Control Limited. Application of the insecticides to the roots or its introduction into holes bored in the trunk both achieved a much higher mortality of mealybugs than is possible by the use of sprays or dusts, but many difficulties remain in the way of large-scale use of systemic insecticides and the difficult problem of investigating the effect of their use on the rate of spread of swollen shoot disease remains to be clarified.

Biological control.—The possibility of effective control of the mealybug vectors of swollen shoot disease by means of introduced natural enemies has never been considered promising. It was considered, however, that the matter should be thoroughly investigated and, with the assistance of the Commonwealth Institute of Biological Control, some species of parasites and predators of species related to those occurring on cacao in West Africa have been introduced and liberated, after mass rearing in appropriate cases. There is little evidence of establishment by any of the species introduced.

TSETSE CONTROL DEPARTMENT, REVIEW OF WORK 1948–54

The work of combating sleeping sickness continued throughout the Northern Territories and Northern Ashanti, resulting in the complete collapse of the epidemics. Sporadic outbreaks still occur along the main trade routes and work continues in accordance with a scheme to break the man-fly contact all along these north–south lines of communication.

Protective clearing in the vicinity of the large towns, ferries and institutions continued in all parts of the Gold Coast.

Tsetse eradication in connection with agricultural development projects was continued in the Gonja district of the Northern Territories where the Gonja Development Company is developing large areas by mechanised operations. In the north-west a simpler type of development has been taking place by clearing whole river basins of tsetse fly, and by building feeder roads and creating perennial water supplies, thus encouraging peasant settlement. The Tsetse Control Department has also begun to open up the vast inter-Voltain territory lying between the two Voltas amounting to some 14,000 square miles.

With the establishment of a station in the north-east, work was begun on the eradication of fly along the main north-south cattle route. Thus it is hoped to reduce the risk of infection in transit animals.

In 1953, the Tsetse Control Department took over game control. Four large game reserves have been established and an organisation has been started to control big game in areas required for development. In this way it is hoped to eliminate *G. morsitans.*

On the research side, entomological investigations were continued mainly by trap survey and age-grouping of eight species of *Glossina* distributed over six climate zones. The infectibility of the fly has been the subject of a special investigation. On the protozoological side the investigation of the haematology and biochemistry of trypanosomiasis was begun.

JAMAICA

REVIEW OF ECONOMIC ENTOMOLOGY

By H. C. James

Plant Protection Officer, Department of Agriculture

A species of froghopper (*Prosapia basalis* Walker) was observed attacking sugar-cane in Jamaica for the first time in October 1951. The Plant Protection Division of the Department of Agriculture, Jamaica, was engaged on a Small Borer survey on the Caymanas estates when the nymphs, enclosed in their characteristic spittle on the roots of cane, were discovered in the Lagoon section of the estate.

Compared with infestations of allied species in Trinidad or South America, the most striking features were the apparent absence of adults and the lack of the lesions produced in the leaf surface by the feeding punctures of the pest. Close investigation round the bases of stools heavily infested with nymphs often disclosed numbers of adults whose habit was generally to remain partially hidden at the foot of canes and seldom to take up feeding positions on the leaves.

When forced to feed on the leaves of cane on plants under cages, visible lesions were either absent or represented by faint markings which bore little or no resemblance to those of the destructive species, the Trinidad Froghopper.

This would appear to indicate that the saliva of the Jamaican froghopper is either innocuous or only slightly toxic and combined also with its cryptophagous habit suggests that even under highly favourable conditions this species would be incapable of causing the severe damage which allied species are able to inflict.

The general survey of the canefields which followed on the discovery of this species of cane froghopper showed that the insect was generally distributed throughout the island and occurred on a number of important estates including Monymusk and Frome.

The alarm was considerable and only abated with the lapse of about a year, during which no significant damage was reported and which gave time for the general bionomics of the species to be better understood. A continuous series of observations in the field in conjunction with breeding work in the insectary indicate that the pest normally increases in numbers both on cane and grasses from about September onwards to the commencement of the dry season in December when numbers gradually decline almost to vanishing point. With the approach once more of the autumn rains general breeding is resumed and the cycle once more repeated. The breeding work in the insectary disclosed that the period of incubation of some of the eggs extended over a number of months as the following Table shows. In this way, eggs may remain dormant but viable in the soil from one rainy season to another.

This information led to a drastic programme being adopted on several estates where the probability of outbreaks appeared to be greatest. Affected fields were burnt off after reaping and then ploughed in and left fallow for as long as possible before replanting. Another point brought out by laboratory breeding work was that the lowest minimum incubation period of the eggs of *P. basalis*, namely 22 days, was about twice as great as the lowest minimum incubation period of the notorious pest species of cane froghopper in Trinidad, Venezuela and British Guiana.

TABLE

Incubation period of froghopper eggs, *Prosapia basalis* Walker

Petri dish no.	No. of males	No. of females	Date set to oviposit	Date set to hatch	Min. incubation period	Max. incubation period	Period of hatching in days	Total eggs hatched	General remarks
1	4	16	22.10.51	25.10.51	25	126	101	69	
2	4	18	23.10.51	26.10.51	22	152	130	64	
3	4	22	24.10.51	27.10.51	25	134	109	69	
4	?	4	25.10.51	29.10.51	25	95	70	25	
5	1	5	26.10.51	29.10.51	43	128	85	23	
6	2	15	27.10.51	30.10.51	27	116	89	14	
7	?	7	29.10.51	1.11.51	47	115	68	29	
8	1	13	20.10.51	2.11.51	—	—	—	—	Nothing further recorded
9	3	16	31.10.51	3.11.51	25	222	197	83	
10	1	13	3.11.51	6.11.51	28	125	97	20	
11	6	22	8.11.51	11.11.51	72	336	264	59	
12	6	14	15.11.51	18.11.51	23	125	102	68	
13	?	19	22.11.51	25.11.51	24	228	204	229	
14	2	9	23.11.51	26.11.51	29	219	190	112	
15	9	11	10.12.51	13.12.51	26	272	246	71	
16	?	?	12.12.51	15.12.51	24	265	241	20	
17	1	10	17.12.51	20.12.51	45	277	232	38	
18	8	12	24.12.51	27.12.51	31	282	251	135	
19	5	10	24.12.51	27.12.51	28	275	247	61	
20	10	22	31.12.51	2. 1.52	29	269	240	175	
21	8	16	4. 1.52	10. 1.52	39	259	220	175	
22	13	13	9. 1.52	12. 1.52	27	222	195	72	
23	?	?	11. 1.52	14. 1.52	27	203	176	107	
24	15	15	24. 1.52	27. 1.52	26	191	165	196	
25	1	15	30. 1.52	2. 2.52	26	203	177	193	
26	10	15	21. 1.52	24. 2.52	25	163	138	250	
27	6	13	7. 3.52	10. 3.52	22	128	106	463	
Average for 26 petri dishes	4·58	12·77			30·38	197·35	166·92	108·2	

There was some suggestion that, as the froghopper season advanced, the period of incubation of the eggs tended to grow longer but probably the volume of breeding work done was insufficient to establish this fully. In any case, the increase in the production of long-period eggs with the advancement of the season was not nearly so marked as in the case of the common species of cane froghopper of Trinidad (*Aeneolamia varia* var. *saccharina*).

In view of what occurred subsequently in the Lagoon and other sections of the Caymanas estate it should be stated that the former area was inundated during the severe hurricane of 1951, but it appears unlikely that this was the direct cause of *P. basalis* attacking cane since froghopper was found on the new host in areas which were entirely unaffected by that hurricane.

There was also strong presumptive evidence that what could be regarded as excessive applications of insecticide were made in an endeavour to eradicate the froghopper on such sections of the Caymanas estate as it was found to occur.

However, whatever was the proximate cause, there gradually grew up one of the most extensive and persistent outbreaks of Canefly (*Saccharosydne saccharivora* Westd.) ever recorded from the canefields of Jamaica.

A mild infestation of Canefly developed in 1952 but it was largely disregarded since it was doing little damage and the habit of this pest to make a short visitation and then to disappear almost completely from causes not always apparent was well known.

By the middle of 1953, however, some hundreds of acres of old cane, particularly of the soft-leaved varieties such as M 28, B 4362, B 37161, were heavily infested. A remarkable feature of the parasitic and predatory complex associated with the outbreak was the great lack of Coccinellids and the few specimens which were found belonged to *Scymnus* and allied genera containing very small-sized species.

The relative absence of ladybirds (Coccinellidae) was due in large part to the activities of adult " Assassin Bugs " (Reduviidae) which are predacious on them. *Zelus longipes* L. (*Zelus rubidus* L. & S.) was the commonest species which occurred. Reduviids were observed to be usually the first of the larger-sized predators to appear in canefly infestations and the harm done by the adult bugs in preying upon Coccinellids was more than offset by the fact that Reduviid nymphs, and to a lesser degree adults, destroy large numbers of canefly nymphs and can be regarded as of first-class importance in assisting control.

Another group of previously unrecorded natural enemies of Canefly in Jamaica was a species of Strepsiptera which was probably *Stenocranophilus quadratus* Pierce (Halictophagidae) which also occurs in Venezuela and Puerto Rico. Stylopised nymphs and adults of the Canefly could be recognised by one or more black dots on the derm usually in the abdominal region where the male parasite was located. The female parasite is less easily seen, being golden brown in colour and more often in the anterior part of the abdomen and hidden from view by the host's wings.

Affected nymphs were able to move about quite readily until the more advanced stages of parasitisation are reached. Stylopid parasitism was very general in its distribution throughout the infested area and frequently a very high incidence was attained.

The Green Muscardine Fungus (*Metarrhizium anisopliae* Sor) was also found to be of first-class importance not only by destroying Canefly directly but also in helping to finish off the individuals which had been stylopised by entering the wound formed by the emerging male Stylopid, a proceeding which rapidly proved fatal to the host.

Another group of hitherto unrecorded enemies of the Canefly in Jamaica was the Syrphids or Hover Flies (Diptera) whose larvae may sometimes be observed doing useful work but are not always present even in a heavy infestation.

A Mymarid egg parasite (*Anagrus armatus*) was of general occurrence but its degrees of parasitism seldom attained those of *S. quadratus*. Another species of parasite (Hymenoptera) of rather rare occurrence has not yet been determined. Lacewing flies (Chrysopidae) whose nymphs had been previously recorded as attacking canefly were sometimes useful.

In order to help build up the Coccinellid population on infestations, 500 specimens of *Coleomegilla maculata* Deg. were imported by air from the rice fields of British Guiana through Dr. F. J. Simmonds of the Commonwealth Institute of Biological Control, Trinidad. *Coleomegilla maculata* is indigenous to Jamaica but the imported specimens died off rapidly or disappeared and failed to become established. A second importation of about 1,000 specimens was similarly unsuccessful.

Another important lacuna in the predatory complex surrounding the Canefly was the lack of an important egg predator comparable to *Cyrtorhinus mundulus* Bredd. of Hawaii.

Consequently, through the good offices of Dr. Simmonds, a series of five weekly air-mailed parcels have been received from the Hawaiian Sugar Planters' Association in Hawaii.

Each parcel contained eggs or early-instar forms of *Cyrtorhinus mundulus*. In order to avoid a heavy mortality of this beneficial insect on its long journey to Jamaica, special methods had to be employed to ensure its arrival in quantity.

First of all, an infestation of the Corn Leafhopper (*Peregrinus maidis*) was built up on maize in an insectary at Honolulu and then *Cyrtorhinus* is released among them under suitable cages. Since the Corn Leafhopper eggs are acceptable to *Cyrtorhinus* the latter develop normally and eggs are oviposited singly or in small groups in crevices in the leaves of the maize. At this stage the maize leaves are cut up into convenient lengths, parcelled and sent to Jamaica.

In an insectary of the Plant Protection Division, the newly-hatched *Cyrtorhinus*, which are minute red-coloured nymphs about 1 mm. long, are collected and liberated daily amidst the egg clusters of the canefly.

When *Cyrtorhinus* are no longer obtainable the maize leaves are burnt since none of the latter are taken on to the sugar estates.

Up to the present about 400 first-instar nymphs of *Cyrtorhinus* have been liberated and it is hoped to continue to receive consignments for some time to come in order to give this egg predator a good chance to become established here.

Another type of predator which is often fairly common in the canefly infestations of Venezuela and Trinidad, but which has not been taken in Jamaica amongst Canefly, comprise species of Dryinids. A common species belongs to the genus *Pseudogonatopus*. The females are apterous and have a remarkable ant-like appearance. The fore pair of limbs are modified to enable the insect to seize a nymph or adult Canefly and then an egg is oviposited in its derm.

The larva develops in a dark sac-like protrusion situated usually on the anterior region of the abdomen. After feeding selectively for some time the larva finally devours the interior of the host. It then leaves the latter and pupates in a white cocoon.

The males are not common and the species is parthenogenetic. Four consignments of *Pseudogonatopus* sp. have been sent by Dr. Simmonds from a canefly infestation in south Trinidad. The best method of transport is in the pupal stage since a high mortality of parasitised canefly nymphs always occurs in transit.

This biological control programme of introductions will continue for some considerable time in the hope of building up the natural enemies of the Canefly to such a point that similar outbreaks will be prevented in the future.

KENYA

REVIEW OF ENTOMOLOGICAL WORK OF THE DEPARTMENT OF AGRICULTURE, FROM 1948 TO 1954

The Entomological work of this Department comprises Agricultural Entomology as usually understood, and includes insects attacking plants and plant products in storage. It is not concerned with insects attacking man or animals.

The work will be dealt with under eight headings:—

(1) Operation of the Plant Protection Ordinance.

(2) Advisory Services.

(3) Important insect pests and their control.

(4) Important Coffee insects and their control.

(5) Insecticides.

(6) Taxonomy.

(7) Stored Products work.

(8) Biological Control.

Since 1948 the staff position has improved and today (April, 1954) consists of a staff of departmental and associated workers, numbering 5 Entomologists and 6 other European workers, together with African subordinate staff. The Coffee Research Station is responsible for the entomological work on coffee.

OPERATION OF THE PLANT PROTECTION ORDINANCE

This Ordinance is concerned with legislative measures to control the spread or severity of pests already in the country and to control the importation of plants with the object of preventing the introduction of new pests and diseases. The administration of the work comes under the Entomological Section, but the Senior Plant Pathologist collaborates on all technical matters. Plants for export are inspected and plant health certificates issued.

Pests and diseases, some of them not occurring in East Africa are often intercepted. For a good many years past the control has been such that no important insect has become established through importation in plant products, though a few have arrived by natural spread from neighbouring countries. New fungous diseases have become established from time to time, though some of these are believed to have arrived in foodstuffs.

Of the means of treating various classes of produce the following have been used:

(1) Fumigation of nursery stock normally carried out is with HCN, generated in one of the fumigation chambers by the action of sulphuric acid on sodium cyanide, the standard dose being 3 oz. of sodium cyanide to 1,000 cu. ft. for 1 hour. This has been found to give a complete kill of mealybugs without damaging plants.

(2) Cut flowers are fumigated to destroy thrips and the dose in this case is generated from 1½ oz. sodium cyanide to 1,000 cu. ft. for 15 minutes. This is effective against thrips, and does not damage the flowers.

(3) Tomato seeds have been treated against *Corynebacterium michiganense* at a temperature of 54° ± 1° C. without impairing germination.

(4) Experiments have shown that fresh fruit may be successfully treated against infestation by several species of fruit-flies by fumigation with ethylene dibromide at 6 oz. to 1,000 cu. ft. for 24 hours.

(5) Methyl bromide fumigation has been found to impair the germination of tea seed. It was suggested that all oil seeds might be affected in the same way but experiments showed that there was no impairment of germination with methyl bromide fumigation of linseed, colza, sunflower, groundnut, castor oil or niger oil seeds.

ADVISORY SERVICES

In the Section there are no purely advisory or extension officers, and this important branch of the entomological work falls to the specialists in addition to their research duties. The advisory work of the section is in two branches (*a*) advice to Government and Government Officers, (*b*) to farmers and members of the public. Under (*a*) comes advice on the necessity or otherwise of legislation such as control of planting dates: on new legislation which may be necessary, for example control of the use of Toxic Chemicals: on organisation of entomological work. Various members of the section have served on or attended the following advisory Committees.

1. Desert Locust Survey Advisory Committee.
2. Pyrethrum Research Advisory Committee.
3. Coffee Research Committee.
4. Pest Control of Stored Products (Interdepartmental) Committee (Chairman).
5. Toxic Chemicals Committee (Chairman and Secretary).
6. Specialist Entomological and Insecticide Committee.
7. Interterritorial Coordinating Committee for Coconut Pest Research.

Under (*b*) comes advice to the public on the control of agricultural insects. A not inconsiderable proportion of the time of Departmental Entomologists is occupied in this way.

IMPORTANT INSECT PESTS AND THEIR CONTROL

Orthoptera

Damage to grazing by grasshoppers was reported on a serious scale in 1950 in part of the Rift Valley. The most important species concerned were *Gastrimargus brevipes* Sj. and *Caloptenopsis glaucopsis meruensis* Sj. though six other species were also numerous. An abnormally low rainfall was believed to have given rise to their unusual abundance. A bait of bran and BHC was reported as giving good results and at the end of the year a big reduction in numbers was noted.

Isoptera

The application of toxic BHC smoke by the technique developed by W. G. Coaton of the Department of Agriculture, South Africa, was used on nests of *Odontotermes badius* Havil. in the Nairobi area. The pressure applicator, made locally, proved satisfactory as did one sent from South Africa. Out of 22 nests treated 17 were completely destroyed by one application. The method is the most effective tried locally but is, unfortunately, too expensive for large-scale use.

Hemiptera

Schizaphis graminum Rond.

Usually only a minor pest, was present in 1952 in the Njoro area on a plague scale. Large acreages of young wheat were wiped out by it though many fields were sprayed with fair results. On isolated farms, where spraying could not be undertaken, crops were ploughed in to prevent further spread of the insect. Two treatments were employed. On the west side of the area "Pestox 101" was used in low volume machines at the rate of between 1 and 2 oz. of active ingredient in 20 gallons of water per acre. On the east side 5 lb. of Agrocide dispersible powder (6·5% gamma BHC) was used in 60 gallons of water per acre at a pressure of 400 lb. per square inch. These measures were successful in limiting the infested area and numbers did not build up where spraying had been done.

Rhopalosiphum maidis Fitch.

Was also present in very large numbers on barley as well as wheat and was controlled by the same insecticides. In the centre of the outbreak area natural control was achieved by the Coccinellid *Adonia variegata* Goeze. but in the meantime heavy crop losses occurred.

Brevicoryne brassicae L.

The mealy aphis of cabbage is a common pest and though usually heavily parasitized as well as preyed on by ladybirds it may completely destroy a crop. Treatment with 0·65% gamma BHC dust has been found satisfactory.

Orthezia insignis Dougl.

At the beginning of the period this was a serious pest of jacaranda trees and many garden flowers. In 1948 the Coccinellid *Hyperaspis jocosa* (Muls.) was imported by the Forest Department from Hawaii and a very small-scale liberation was made, this established itself but did not become numerous. A further importation was made by the Forest Entomologist in 1950 and further small liberations were made. In 1951 this section was asked to undertake large-scale rearing. This was carried out successfully and over 100,000 ladybirds have been liberated. The degree of biological control since achieved is such that control by insecticides is generally considered unnecessary and in some areas *Orthezia* is now difficult to find.

Aonidiella aurantii Mask.

This major pest of citrus has been partially controlled by 0·03% parathion. Preliminary trials with malathion (0·2% with 2% white oil emulsion added) have showed promise and further tests against this pest are to be carried out when larger supplies of malathion are available.

Coccus hesperidum L.

Parathion at 0·03% gave a complete kill with this species.

Aspidiotus hederae Vallot.

This has been controlled by parathion at the strength of 0·07%.

Aulacaspis cinnamomi Newst.

This very common pest of mango was controlled in trials with a malathion spray (0·2% with 2% white oil emulsion).

Lepidoptera

Busseola fusca Fuller

The maize stalk borer is one of the major insect pests of the Territory. It is widely distributed both in African and European farming areas but in the former normally no attempt is made to control it by insecticides. In the densely populated areas where maize plots are numerous it is usually abundant. In spite of propaganda from the Agricultural Department no African community seems to be prepared to carry out simple hand dressing, though many Africans are well acquainted with the method through their work on European farms and despite the fact that the treatment is cheap, easy to apply and effective. In 1949 the life cycle of the insect was studied at Kitale, the centre of a large maize-growing area. There were two generations in the year, the first from May to July or August in young maize plants and the second and partial third from August to April in maturing plants or their residues. The first generation, which occurs in maize from about a foot high, can be controlled by insecticidal dust or liquid poured into the "funnel" of the plant. The second generation, which bores into the maturing plant, is very difficult to control and so it is necessary to aim at 100% kill of the first generation. Large second generations and possible third or even fourth generations are prevented by Planting Rules. These limit the planting of maize seed to a short season, to ensure a maize-free period prior to planting. The second generation passes the dry months—November to March—in the maize stalk and in years of heavy infestation this may have to be burnt under a compulsory order. Normally, however, the second generation caterpillars tend to die in the dry months—many are parasitised by *Apanteles sesamiae* Com.—and their numbers decline considerably. Pupation occurs at the onset of the rains and the adult moths are on the wing when the new crop is growing up. In the Nairobi area an egg parasite has been found recently but has not yet been identified. It has been found that the 1st-instar larvae remain for a long time on the surface of the leaves and are therefore vulnerable to insecticides for two to three weeks. The characteristic damage of 'windows' in the maize leaves is not seen until 6 to 10 days after the hatching of the eggs. When this is visible hand dressing of the maize with 1% DDT in diatomite or "Derrisol", 1 part in 700 of water, is effective; this is followed by repetition of the treatment about three weeks later where it is necessary. Because of difficulty in obtaining labour some farmers are now carrying out spraying of the crop with a DDT emulsion—usually with low volume boom sprayers. Aircraft spraying with a 2½% DDT emulsion was carried out by the Colonial Insecticide Research Unit, in collaboration with the Agricultural Department in the Nakuru area in 1953. Unfortunately a period of drought followed, seriously interfering with the growth of the maize. In one trial the infestation in treated hills rose from 1·25% to 4·04% in eight weeks whereas in the untreated hills the corresponding figures were 2·5% to 10·38%. Under the conditions existing the aerial spraying was not sufficiently effective.

In laboratory tests using DDT in local diatomite, 1% DDT gave only 79% kill in 24 hours with 1st-instar larvae as against 100% kill with 2·5%. In small-scale field tests however, 1% DDT has usually proved effective. Derrisol, 1 in 700, was equally good in the field though laboratory tests showed no residual effect. In Potter tower tests, gamma BHC gave a quicker and higher kill than DDT with deposits in the range 3 to 55 mg./sq. metre. Where the larvae were allowed to crawl on deposits on maize leaves however, gamma BHC was inferior to DDT. Isodrin was more effective than DDT while endrin was less so. Field trials involving the use of sprays on infested sorghum are in progress, hitherto control of the borer in sorghum has not been attempted.

Heliothis armigera Hb.

This is an important pest of maize and particularly of cotton. Considerable damage can occur in both crops but in cotton a high percentage of bolls are sometimes lost through its attacks. Its life cycle and especially its movements from one host plant to another are being made the object of a special study in the Nyanza Province. In tomatoes good control has been achieved with 0·05% DDT spray.

Euxoa sp., *Polia* sp. &c.

Cutworms are sometimes major pests of different crops at planting time. Baiting with 2·6% gamma BHC at the rate of 4 oz. to 6 lb. of bran or maize meal is effective, though rather expensive for large-scale use.

Laphygma exempta Walk.

This Armyworm occurred in January, 1949, on a large scale and a DDT spray of 0·1% and a dust of 2% were found effective. A heavy infestation occurred again in December, 1953, and field tests were undertaken. Endrin at 5 oz. per acre (an emulsion of 0·065% at 50 gallons per acre) gave 99·5% kill after 18 hours. Isodrin at the same strength gave 90·5% and DDT at 7½ oz./acre (0·1% emulsion) gave 97·4% which increased to 100% after 8 days. Of dusts used, parathion was the most effective, a 0·75% dust gave 94·8% kill but it appeared to have little residual effect and its use is not recommended in practice. In further tests endrin emulsion at 2½ oz. per acre gave 100% kill in three days and was more effective than DDT. At present because of its availability DDT remains the standard control.

Plusia orichalcea F.

This caterpillar, known locally as the Flax Caterpillar is a general pest of flax, maize and legumes and other crops. In 1953 it occurred on wheat causing heavy damage by feeding on the green ears. Control was not employed against it but a high percentage of the larvae were parasitized. In kale, DDT wettable powder was used successfully against it at the rate of 1 lb. DDT to 100 gallons of water.

Marasmia trapezalis Guen.

A serious outbreak of this moth occurred in maize in Nyanza and the north-west part of the Rift Valley Province. It was far too widespread for control measures to be undertaken. Only one destructive generation was reported, as is usual locally, since further generations are effectively controlled by natural enemies.

Coleoptera

Schizonycha spp.

Experiments carried out against these Melolonthids in the Kitale area, where the grubs are general root feeders, have shown that benzene hexachloride is only effective at high concentrations, too high to be a practical economic control. In 1952–54 small-scale tests gave promising results with aldrin. In small plots, 2½% aldrin at 40 lb. per acre (1 lb. technical aldrin per acre) applied in the fertiliser to barley was more effective against the chafer grub than aldrin used as a seed dressing. Mergamma " A " or Mergamma " B " as seed dressings have been shown to give a measure of protection against the grubs.

Heteronychus consimilis Kolbe.

The attacks of this beetle on wheat, particularly in the Ol Kalou area have led to heavy losses in the past few years. Experiments showed that improved yields were obtained from the use of Mergamma " A " seed dressing (3 oz. per bushel) and of aldrin 2½% dust drilled at the rate of 18 lbs. per acre with fertiliser (equivalent to 7·2 oz. per acre of technical aldrin). These results were confirmed in trials carried out in 1953, and these are becoming standard control measures.

Nematocerus spp.

Weevils of this genus have been reported as pests of vegetables, maize, wheat and wattle. Heavy damage to young wattle occurred in 1949, the seedlings being defoliated as they came through the soil. A bait of chopped maize plants containing 2½% by weight of 2·6% gamma BHC proved effective but the trouble occurred again in 1950 when no maize was available. A bait of couch grass, BHC and molasses was then found satisfactory. Elsewhere a bait of maize flour, sugar and 2·6% gamma BHC in the proportion 120:5:8 gave good results in maize. The same, or a closely related species did heavy damage to maize in 1949 and in one case replanting had to be carried out three times. Larvae of one species were reported as damaging the roots of wheat.

Dasus simplex F.

This continues to be a general pest particularly of seedlings. Replanting of maize may be necessary, this was the case at Kitale in 1949. Dressing the seed maize with 1 lb. of 2·6% gamma BHC per 200-lb. bag prevented damage to the second planting and an extremely good stand of maize resulted. Heavy losses to wheat were reported from a farm in the same area and a bait of $2\frac{1}{2}$% by weight of 2·6% gamma BHC in maize flour gave good control. The bran bait used against cutworms is also effective.

Epilachna hirta Thunbg.

Species of *Epilachna* including the above are reported annually as pests of young barley, maize, potatoes and other crops. Five per cent. DDT dust has been found effective but on a field scale it is generally too expensive to apply.

Acanthoscelides obtectus Say.

Many species of Bruchids occur as pests of legumes and heavy infestations occur in stored pulses. In 1953 a test to ascertain the degree of field infestation of haricot beans by *Acanthoscelides obtectus* Say was carried out. Only about 1·2% beans were infested in the field. Where DDT dusts were applied the percentage infested was slightly lower but with these low populations it is obviously uneconomic to apply them.

Oryctes monoceros Ol.

No easy control of this serious pest of coconuts by insecticides is possible but numbers can be reduced by plantation hygiene, removal of dead and dying coconut palms, and the regular removal of the larvae from compost, manure heaps and any pile of rotting vegetation. The destruction of dead and dying coconut stems is enforceable by law, and as this has been applied with success in some areas it is planned that it should be more widely enforced. Pits filled with rotting banana—and other trash, inspected at intervals to remove all beetles, are effective traps but their value has not been proved by experiment on a large scale. *Scolia ruficornis* F. is normally the major parasite of this species but does not prevent serious damage. Muscardine fungus *Metarrhizium anisopliae* has also been reported but could not be transmitted to larvae in the laboratory, and clearly does not exert a very high degree of control in the field.

Diptera

Fruit-flies

In preliminary tests using *Ceratitis capitata* Wied. a bait of sugar and malathion showed promise. The bait contained malathion at the rate of one part to 64 of sugar to 1280 of water.

Hylemyia arambourgi Seg.

A dipterous larva in barley, first noticed in 1952, became a pest in the following year. Adults bred out proved to be *Hylemyia arambourgi* Seg. The larva lives in the central shoot of a barley plant or sometimes in wheat. The plant may die, particularly in drought conditions or it may tiller and survive. Insecticides applied by commercial firms were not very effective. Opportunity for experimental work on this insect by this Department has not occurred.

Important Coffee Insects and their Control

Common Mealybug, ***Planococcus kenyae*** **(Le Pelley)**

Since the establishment of biological control for the common mealybug, its status has declined from that of a very serious major pest, to a pest causing only occasional serious loss in limited areas. The biological control position has been described in a note prepared for the Commonwealth Institute of Biological Control.

In African areas, on food crops the mealybug now does little or no damage, the former serious loss does not occur, and the establishment of biological control has been of incalculable benefit in African areas. In coffee it is still a pest to be reckoned with and work has continued on the following lines:

(i) The search for better chemicals or methods to use against the ant, *Pheidole punctulata* Mayr., has gone on. DDT emulsions were first used in place of the old-established banding-grease method. These proved disappointing in general because attendance by ants was not completely cut off and although vast numbers of ants were killed it was found in practice that this did not make any impression on the immense ant populations in coffee plantations. BHC was used in various formulations to keep ants off the trees. These were quite successful in the absence of rain but had to be renewed after even small amounts of rain had fallen. Since research has conclusively proved that BHC insecticides impart a taint, known as "bricky flavour", to coffee they are no longer used. During this period banding-grease was still recommended though considerable difficulty was experienced in getting satisfactory greases. More recent research has proved the effectiveness of dieldrin and chlordane bands. At strengths and rates of application recommended no taints have been associated with their use. The dieldrin strength now recommended is 1 part of dieldrin 19% emulsion in 20 parts of water. Two dyes, methylene blue and malachite green, have been tested and approved as inclusions to make complete coverage of the stems easier to see and attain, and are used at the rate of 2 ounces in 10 gallons of diluted insecticide. A spray-banding open ring, which carries three T-jet nozzles, designed by Pest Control Ltd., is a very useful tool for applying the emulsion to coffee stems when used with a pressure sprayer.

(ii) The systemic insecticide " Hanane " appears to suffer from too many practical difficulties to be recommended. Work with this chemical has not been carried out by this Department nor is it contemplated.

(iii) There seems some case for bearing in mind parathion sprays together with chemical banding to suppress serious infestation and save crop, but restrictions on this method seem to revolve around the impossibility of enforcing the period during which picking must not be carried out. Opportunity has not yet occurred to try malathion, the less dangerous phosphorous insecticide.

(iv) In general, the new chemicals have so improved ant control that the power of the biological complex has been greatly enhanced and the pest potential of the mealybug reduced accordingly.

(v) Banding grease is now a thing of the past except perhaps for the African growers, but the mealybug attacks have not been so serious in African areas.

Antestia spp.

Still a major pest. The use of DDT for its control is increasing; it is effective, and provided " blanket " treatments are not used, does not always cause an increase of other pests. The effect of persistent insecticides on pests normally controlled by parasites, such as mealybug, tingid bug (*Habrochila placida* Horv.) leaf miner and others has to be borne in mind.

For *Antestia* control it is now recommended that spraying should follow population testing by the old methods, should be staggered in time, and less persistent materials used in presence of mealybug or other pests.

Thrips, *Diarthrothrips coffeae* Williams

Is still a serious pest, controlled by paris green-molasses or DDT.

Stem-borers

These are now being controlled with an ethylene dichloride-carbon tetrachloride mixture inserted into the tunnels in the stem. Dieldrin and other insecticides may be used in future.

Leaf-eating Caterpillars, Beetles (*Systates* spp.) and other Leaf-eaters

These are controlled as before by lead arsenate, but sometimes DDT emulsion is used at 0·1% DDT.

INSECTICIDES

Use of insecticides has been mentioned many times under various pests. The Department is not concerned with purely fundamental studies, but with such laboratory work as is required to guide eventual field application. The section is now fitted with an insecticide laboratory in which such studies can be undertaken when staff permits. During part of the period under review an Entomologist was posted from Colonial Insecticide Research who carried out studies on insecticides against Stalk borer of maize, chafer grub and other subjects, the main practical results of which have been reported under the different insects concerned.

TAXONOMY

A systematic study of Ethiopian Coccidae has been started in the last two years, designed primarily to assist in clearing up the considerable confusion existing. During this work many undescribed species have been found and are now in process of description. A study of certain Diaspididae of Kenya and other East African areas has already been made. A study has now begun of the Ethiopian mealybugs (Pseudococcidae). This study is being undertaken jointly with the Commonwealth Institute of Entomology, and should clear up the great confusion at present existing in the taxonomics of this important economic family in this region. This will require a number of years of careful work, but will be of value throughout Africa and also to all countries importing plants trom Africa.

STORED PRODUCTS WORK

An Interdepartmental Committee was formed in 1949, the Pest Infestation of Stored Products Committee, to keep the subject under constant review and to advise Government on all aspects of the subject. This Committee consisted of the Senior Entomologist as Chairman, the Maize Controller and a member of the Medical Department. On the recommendations of this Committee an Inspector (Scientific Officer) was engaged in 1950 and an Entomologist in 1952 working at the Scott Agricultural Laboratories under the direction of the Senior Entomologist, thus enabling the work under this heading to be stepped up.

Experimentation has been carried out on the following lines:—

Heat treatment of maize in a grain conditioning plant delays the severe build up of an insect population in bagged grain for many months but does not completely disinfest grain, and by itself is not sufficient for the successful storage over prolonged periods under local climatic conditions.

Experiments with bag material impregnated with insecticides have been carried out. None of the treatments have given protection of fumigated grain for more than short periods under our conditions.

Fumigation of grain stacks with methyl bromide under balloon fabric has been tried. The experiments with this promising method were held up by emergency storage needs and the practical application by lack of trained staff. There is little doubt, however, of the value of the method for the control of *Calandra oryzae* and other storage pests. It is also believed that methyl bromide fumigation may assist in producing haricot beans suitable for export to canners and if so an important industry may become established in some districts of Kenya which are eminently suitable for this crop.

Experiments with maize on the cob stored in open cribs were started in 1952. Eight ounces of 0·4% gamma BHC in local diatomite per 9 cu. ft. of maize on the cob gave almost complete protection for over 6 months. A 22·7% saving in weight of shelled maize was obtained. It was also shown that most of the BHC was removed during the ordinary shelling process. A lower concentration is effective inside the bulk than is effective on exposed sides. Under trial are different treatments of the exposed sides of the cribs.

Large-scale experiments with various insecticides applied to shelled maize in 200-lb. bags were started in 1948 and the results obtained have been published (*Bull. ent. Res.* **45,** part 2, 1954).

Inert dusts tried in our experiments are Kenya diatomite, a local bentonitic clay and a local soapstone. It has been found that the slippery nature of diatomite and soapstone dusts tend to inhibit free movement and breeding through the bulk, and this may be the chief reason for their practical effect.

Diatomite of high quality, which is present in Kenya in very large deposits, has been found to be an outstanding diluent for insecticidal dusts. The local product is a lacustrine diatomite composed predominantly of species of *Melasira.* When powdered it has a more fine-grained and generally more even-grained nature than many diatomites. The colour is pure white. When applied to grain, most of it can be easily removed by blowing. When mixed with BHC to give 1 p.p.m. of gamma BHC in grain it has been found completely to prevent insect infestation in bagged maize stored in a heavily infested store for 16 months and it gave almost complete protection for two further months in an experiment. Pyrethrum powder, using 6 oz. or over to a bag, to give a pyrethrin content of 25 parts per million of grain, has given good protection up to 10 months. When experimenting with pyrethrum, results were often confusing. In several instances higher damage in grain treated with pyrethrum than in untreated controls was obtained. This was found to be due to its effect on the parasites.

Anisopteromalus (*Aplastomorpha*) *calandrae* (How.), under Kenya conditions, has a marked effect on the progress of weevil infestation in grain. While in a bulk or tightly packed bag stack the heat and moisture conditions produced by the insect population determines the course of infestation, this does not hold for the conditions in exposed surfaces of grain or in maize cobs stored in an open crib. Under such conditions a high infestation may build up before the parasites increase. When the parasites catch up, the population is reduced and thereafter tends to remain, with minor fluctuations, at a much lower level. It is during the first months of storage therefore that the bulk of the damage is done.

BIOLOGICAL CONTROL

Detailed results have been provided to Dr. Thompson, of the Commonwealth Institute of Biological Control, so projects undertaken in the period under review need only be shortly summarised here.

(1) Control of *Orthezia insignis* Dougl.

A good measure of practical control has been achieved by introduction from Hawaii of *Hyperaspis jocosa* (Muls.) (Coccinellidae). Further parasites and predators are in process of rearing or importation from Trinidad.

(2) Control of chafer grub, *Schizonycha* (Melolonthidae).

Scoliids have been introduced from Mauritius and liberated but establishment is not yet confirmed.

(3) Control of the weed, *Lantana camara.*

The Tingid bug, *Teleonemia scrupulosa* Stål, introduced from Hawaii, has been successfully reared and liberated, and appears to be in process of establishment. Local predators of the bug are causing anxiety.

A number of beneficial insects have been exported to various countries, several of which have become established. The work, both import and export, yearly increases in importance and requests for help are already well beyond the resources of this Department.

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MALAYA

RÉSUMÉ OF ENTOMOLOGICAL WORK, 1946–1953

Department of Agriculture, Federation of Malaya

Immediately after the war things were disorganised, equipment was in bad condition or lost and much of the reference collection had been removed. Most of the collection was recovered, though in poor condition, from Singapore, but the collection of Diptera, which included a number of paratypes and was contained in a 20-drawer cabinet, was not recovered, though the empty cabinet was found with the rest of the collection.

During the Japanese occupation of Malaya the entomological laboratory had, for some obscure reason, or perhaps for no reason at all other than a craze for " re-organisation ", been converted into the departmental library.

Much early work was connected with food production problems and a number of pests which had received little attention before the war came under notice, partly due to the fact that supplies of derris root, which was regularly used by market gardeners before the war, were almost unobtainable, and partly due to the large acreage put under food crops. The uses to which DDT and BHC could be put were, in the early stage after the war, not fully known, nor was their effect on crops and their possible health hazard. Insects which came under particular notice at this time, and which had not previously been fully investigated in Malaya, were *Phyllotreta cruciferae* Goeze, *P. sinuata* Steph. and *Melanagromyza phaseoli* (Coq.).

PESTS OF RICE IN THE FIELD

Stem-borers (Lepidoptera)

Of the numerous insect pests which attack the rice plant the stem-boring caterpillars of Pyralid and Noctuid moths are probably the most important; they are found in both wet and dry rice, and they occur wherever rice is grown in Malaya and are present throughout the year. Four principal species are concerned:

Pyralidae: *Proceras polychrysus* (Meyr.)
Chilo suppressalis (Walk.)
Schoenobius bipunctifer (Walk.)

Noctuidae: *Sesamia inferens* (Walk.)

It would be difficult to say that any one of these is of greater importance than the others, though records show that *P. polychrysus* has been received more frequently than the other three, while *Chilo suppressalis* has been received least often.

Due to their sheltered mode of life, and to the fact that there are no clearly defined generations under Malayan conditions, it is unlikely that insecticidal treatments will give effective control. The larvae are exposed only for a brief time, the period of distribution which, in the case of *Schoenobius* at least, is largely by air currents, before they bore into the stems of the rice plant. The timing of insecticide application to destroy larvae during this brief period is not possible because, under local conditions, it is of daily occurrence once the rice is planted. Stem-borers may even attack the plants while still in the nursery. One other factor also enters the problem when considering the possible use of insecticides for the control of stem-borers in rice and that is the effect which this may have on the fish in wet rice fields. The fish, *Trichogaster pectoralis* (Regan), known locally as *sepat siam*, is a valuable food fish and a not inconsiderable source of income to rice planters in certain districts, and any insecticide which has an adverse effect on this fish, however effective it might be against the stem-borer, would be highly unpopular with the cultivators.

Despite the difficulties of applying insecticides to the rice plant, in the right place and at the right time, and having due regard to the possible consequences to the fish population, it was clearly desirable to ascertain whether any of the readily obtainable newer insecticides might prove satisfactory, and, if they showed promise, to endeavour to devise some means of using them without hazard to humans or to fish.

The insecticides available at the time were DDT, BHC, toxaphene and parathion. Of the first three, only dusts were available, and these were used for small-scale field trials, the first of which was carried out in 1947.

In 1948 a field trial was carried out in which a rice nursery was divided into 3 sections, one dusted at weekly intervals with 5 per cent. DDT and another with a dust of crude BHC containing 0·65 per cent. gamma isomer. The third section was control. Eight treatments were given in each case in an attempt to obtain borer-free plants for transplanting. At the final stem counts plants from the treated sections showed 28·0 per cent. borer attack for the DDT treatment and 24·0 per cent. for the BHC treatment, against 64·0 per cent. for plants from the untreated section in the nursery.

In a further trial, in 1949, dusts containing 5 per cent. DDT, 0·65 per cent. gamma BHC and 20 per cent. toxaphene were used. Treatment was applied to the nurseries only, 3 treatments at intervals of one week being made. The results were again negative. The percentage of damaged tillers were 60·7 with DDT, 70·7 with BHC, 72·7 with toxaphene and 66·2 for the controls.

Laboratory trials with parathion were not successful except where there was actual contact between the insecticide and the borer larvae, and since this cannot be achieved in the field this investigation was not pursued.

Trials are currently in progress with dieldrin and, following information received regarding success claimed in Japan, with ethyl p-nitrophenyl thionobenzene-phosphonate (EPN).

The possibilities of biological control of rice stem-borers have also received attention, the first attempt in Malaya being initiated in 1929 when the egg-parasite *Trichogramma japonicum* Ashm., which occurs naturally in eggs of *Proceras*, *Chilo* and *Schoenobius* in Malaya, was mass-produced and released in several experimental areas. Although very large numbers of parasites were released, far beyond economic practice, no noticeable reduction in borer attack was achieved, and in 1938 the possibility of introducing the Amazon fly, *Metagonistylum minense* Towns., was discussed. At that time the insect now known as *Proceras polychrysus* was believed to belong to the genus *Diatraea*, in which it was placed by Meyrick. At least one consignment of *Metagonistylum* was despatched from British Guiana by L. D. Cleare and it was intended to test this insect, under laboratory conditions, against *Proceras* and *Chilo*. Unfortunately the despatch of these parasites coincided with the outbreak of war in Europe, and the consequent delays resulted in the death of all of them before they even reached England.

In 1951, puparia of *M. minense* and of *Paratheresia claripalpis* Wulp, were received by air from Trinidad and were tested on both *Proceras* and *Chilo* in the laboratory in Kuala Lumpur. No success was achieved with *M. minense*, but *P. claripalpis* was successfully reared on both *Proceras* and *Chilo*, and it was decided that a field trial with this species should be carried out in 1952. For this purpose an area in which two crops of rice are grown annually was chosen, it being considered that this would give the parasites a better chance of establishing themselves than in a single crop area where the borer population drops suddenly after harvest, the borers maintaining themselves in small numbers in natural grasses. A preliminary survey showed both *Proceras* and *Chilo* to be present in fair numbers in the area chosen and the first flies were released in April 1952. For this trial the parasites were sent by air, as puparia, at weekly intervals, from Trinidad. A total of 8,187 flies were released over a period of 26 weeks. No recoveries have so far been made.

Scotinophara coarctata **(F.) (Rhynchota, Pentatomidae)**

This bug attacks both wet and dry rice and may cause considerable damage. While it occurs in all parts of the Peninsula there seem to be certain well defined areas in which it is of more frequent occurrence than elsewhere. The evidence for this belief is not conclusive: such evidence must, of necessity, be obtained from reports sent to the Entomological Division and outbreaks are not always reported.

Attack by this insect may occur in the nursery or after the rice has been planted in the field, but in the latter case it often happens that the pest was already present in the nursery and was carried into the field at transplanting, the egg-masses on the seedlings not being noticed.

This insect normally lives low down on the rice plant where the stems are densely packed and where it is difficult to reach with insecticides.

Tests in the laboratory were carried out in 1947 with 5 per cent. DDT dust and also with a BHC dust of 0·65 per cent. gamma content. All stages were found to be highly resistant to both these insecticides, but a mixture of the two dusts in equal proportions by weight gave kills of 100 per cent. of adults in 48 hours. The young stages were more resistant and the kill obtained was 70–100 per cent. of mixed instar nymphs. This mixture was subsequently tested in the field and favourable results were reported in 1948.

Also in 1948, laboratory tests were carried out with 20 per cent. toxaphene dust and kills of up to 100 per cent. of adults were obtained.

It is of interest to record that *Scotinophara* is sometimes attracted to light in vast numbers. In January and August 1946, and June 1947, enormous numbers were seen round street lights in Kuala Lumpur town, the insect being present in thousands round each light in several streets, and the total number present must have been in the neighbourhood of several million. Again, in September 1951, this insect was reported round lights and entering houses in similarly vast numbers at Batu Arang coal mine. The cause of these sudden occurrences at light, and the origin of the vast numbers seen, has not been discovered. No reports of outbreaks at these times were received and there is no rice cultivation anywhere in the near neighbourhood.

Leptocorisa acuta **Thnbg. (Rhynchota, Coreidae)**

This bug attacks the ears when they are in the milk stage, and can cause very severe losses. Outbreaks appear to be rather regular in certain areas and seem to be associated with small to moderate sized areas of rice with a good deal of scrub and secondary growths in the immediate vicinity.

The insect is very susceptible to BHC and the effect of dusting a small area with this insecticide (0·65 gamma isomer content) was spectacular. Adults disturbed by the operation flew to a height of 10 to 15 feet and then fell back into the water. This BHC dusting was designed to protect a small varietal trial, but there was a re-invasion of the treated area from neighbouring rice fields, which had been planted later and in which the pest was not present at the time of the treatment.

Provided that planting is carried out at the same time in any given area, and that varieties of similar maturation period are grown, it should be quite possible to control this pest by dusting with BHC.

Trials with insecticidal fogs containing either BHC or DDT are projected but no opportunity to use these has so far occurred since really light-weight apparatus has been available.

Spodoptera mauritia **Boisd. (Lepidoptera, Noctuidae)**

This insect, commonly known as an army worm, is too wel known to need description. It attacks wet rice only in the nursery and reports of outbreaks on this crop after it has been planted out have invariably proved to be some other caterpillar and to be greatly exaggerated both as regards numbers and area affected. The leaf-folder, *Cnaphalocrocis medinalis* Guen. [Pyralidae] and the padi skipper, *Pelopides mathias* (F.) [Hesperiidae], which are seldom serious in Malaya except in small patches, have both been reported as " army worms ". The habit of the caterpillars of *Spodoptera* is to hide in the soil by day, and pupation also takes place in the soil. Clearly, therefore, it would not be found on rice plants growing in water.

The caterpillars can be readily controlled with extract of derris root in water, but this was almost unobtainable after the war and tests were carried out with Gammexane D.034, 2 per cent. DDT dust and a 0·25 per cent. DDT emulsion, in 1947. All were highly effective. Subsequent tests in 1948 showed that dusts containing only 0·25 per cent. DDT were effective against the first four instars, but not against the fifth instar.

There have been reports of *Spodoptera* attacking dry rice over considerable areas, but they have been in inaccessible places and confirmation by a visit has not been possible.

Late reporting of its occurrence is invariably the main cause of serious damage by this pest.

Patanga succincta (L.) (Orthoptera, Acrididae)

This large grasshopper, sometimes known as the Bombay Locust, has recently come under notice in Malaya and although it attacks various crops, is included here because it is more frequently reported on rice than on other cultivated plants. As far as the rice plant is concerned *Patanga* attacks only varieties grown on dry land. Indeed, in one case where wet rice was planted in a narrow strip along a stream, with dry rice on the slopes on either side, *Patanga* actually seemed to avoid the wet rice, though it was numerous on the dry rice. *Patanga* does not appear to be a major pest in Malaya and there is no authentic record of more than 100 acres being destroyed, though the writer was informed verbally in 1946 that 300 acres of hill rice was destroyed in one area in the latter part of 1945. Outbreaks seem to be closely associated with new clearings from jungle, the grasshoppers invading the area as soon as food crops are planted. A migrating swarm has never been observed in Malaya and nothing resembling a swarm has been seen on the ground. Reports of the appearance of this grasshopper in pest proportions have invariably been greatly delayed and, if anything in the nature of a true swarm has occurred, this delay would account for the lack of records, the insects dispersing over the whole cultivated area before a visit could be made.

There have been reports of eight outbreaks since the war, one in North Perak in 1946 when about 60 acres of hill rice and maize were completely destroyed, and seven in Pahang during 1952 and 1953. The Pahang outbreaks occurred in five places in a triangular area with a base of about 19 miles and sides each about 12 miles as measured on the map. Two areas experienced outbreaks in 1952 and 1953, the second outbreak, in each case, starting in new clearings which were extensions of the areas cleared in the previous year. The largest total loss of crop in one area was equivalent to about 40 acres representing about 4 per cent. of the crop from that area. This loss was caused wholly by the insects eating the ripening grain, not by total destruction of the plant.

It has been a popular belief in Malaya that *Patanga* will not take poison baits, but this is not so. Considerable success was achieved with a bait consisting of paris green and rice bran, and dead adults collected in the field were found to contain 8 p.p.m. of arsenic expressed as As_2O_3. *Patanga* bred in the laboratory were attracted to, and readily ate, moistened rice bran after they had reached the sixth instar, but the earlier instars were not at all attracted.

A detailed account of *Patanga* in Malaya is in preparation and no further remarks need be made here.

PESTS OF RICE IN STORAGE

Losses caused by insects to stored rice became a major problem when stockpiling was first put into effect on the outbreak of war in 1939 and this problem has received considerable attention ever since.

From 1939 up to the end of 1941 attention was directed towards ensuring a low moisture content in the grain to be stored and to an investigation of various inert dusts for the treatment of milled grain. At that time it was the practice in the Government Rice Mills to add 5 per cent. by weight of slaked lime to all grain milled, it being claimed that this gave good protection against attack by the rice weevil, *Calandra oryzae* (L.). Laboratory investigations did not support this claim and various other dusts were tested. Of the dusts tested, anhydrite at 1 per cent. w/w was found to give almost complete protection to grain stored in bags for a period of at least six months, and precipitated chalk at the same rate of application was very nearly as good. At 5 per cent. w/w precipitated chalk gave excellent protection over a period of eighteen months. This investigation was completed during the occupation by Enche Kamardin bin Bahar, a Malay Agricultural Assistant, without the knowledge of the Japanese.

After the war, with the advent of DDT and BHC, trials were carried out with these insecticides. Preliminary trials were carried out in the laboratory in 1946. Milled rice was fumigated to free it from insect attack and was then placed in small bags which were dusted with 5 per cent. DDT in talc, Gammexane D.034 and Gammexane D.034 mixed with an equal weight of talc. These bags, with an equal number of untreated bags, were placed in an insect-proof cage into which *Calandra oryzae* was introduced. A heavy infestation of *Calandra* developed in the untreated controls but there was no infestation in the treated bags. External treatment of other bags with a spray consisting of 5 per cent. DDT in kerosene gave similar results.

Before proceeding to a large-scale trial, a test was carried out to ascertain the possible health hazard from rice stored in sacks which had been treated with DDT applied as a 5 per cent. spray in kerosene as reported on p. 82 of the Report of the Fifth Commonwealth Entomological Conference.

A trial on a moderate scale was carried out in 1947 at the Government Rice Mill in Alor Star, Kedah (North Malaya). The rice store treated was of 10,000 tons capacity and the treatment carried out was as follows:—the walls of the store were sprayed with a 3-foot-wide band of 5 per cent. DDT in kerosene to give a deposit of 70 mg./sq. ft. Treatment of padi husk and matting, and of each layer of sacks at the rate of 1 oz. 5 per cent. DDT dust per 4 sq. yds.

This treatment was so satisfactory that it was introduced into all Government rice mills without further prompting by the Department of Agriculture.

The DDT treatment has now been replaced by treatment with Gammexane Insect Powder, a preparation based on technically pure gamma isomer of BHC. That BHC was not used in the earlier large-scale tests was entirely due to the irritating effect of the crude preparation on the eyes, nose and throat observed in preliminary small-scale dusting experiments.

The outside of the sacks of all rice now stored in Malaya is dusted with Gammexane Insect Powder as the sacks are received into the store at a rate of 1 cwt. per 400 tons (4,000 bags).

PESTS OF COCONUT AND OIL PALMS

Artona catoxantha Hamps. (Lepidoptera, Zygaenidae)

There has been no change in the general policy regarding recommendations for the control of this pest of the coconut palm, and it is considered that it would be unwise to try any chemical control measures against this insect, except in special circumstances, without a very full investigation of its ecology. Such an investigation would require the full time attention of one entomologist and several assistants, and it would almost certainly take several years. There seems little prospect of such research being carried out in the foreseeable future.

The present procedure, when an outbreak is reported, is to determine the extent of parasitism by the two common parasites, *Ptychomyia remota* Ald. and *Apanteles artonae* Wilkn., and then to decide whether any control measures are desirable, having due regard to all the other circumstances of the attack. If any action is taken at all it must be thorough. Half-measures are likely to result in increased trouble. If the area attacked is small and parasitism is low, the application of an insecticide, either as a dust or spray, may be expected to give good results if carried out thoroughly: lead arsenate, DDT or BHC are all suitable.

In only one instance has an outbreak of *Artona* in Malaya covered a very large acreage and persisted for a long time, and it seems almost certain that the cause of this was the application of a contact insecticide (BHC) to part of the affected area when the attack was first noticed. The actual number of palms sprayed has not been ascertained with certainty, and the fact that spraying had been carried out was only discovered by chance after the outbreak had got out of hand. So far as is known, the attack was first noticed in an area of about 15 acres of dwarf palms and some of these were sprayed with BHC. When this information was first obtained it was stated that about five acres had been sprayed, but this was later denied and five palms was quoted. Whether anyone would be likely to spray five palms in an area of 15 acres attacked by a pest is best left to the imagination. The parasite *Ptychomyia* is an active host searcher and, assuming that it was present, it is quite possible that a number was killed as a result of visiting the sprayed palms. That parasitism remained low for a long time, while it was high on a neighbouring estate which experienced an attack by *Artona* at the same time, separate and distinct from the first mentioned outbreak, lends support to the view that the treatment did have an adverse effect on the parasite.

Seven months after the outbreak was first noticed parasitism on the first estate varied from 30 per cent. to 63 per cent. while it was from 81 per cent. to 86 per cent. on the second.

The habits of *Artona* in Malaya appear to differ considerably from its habits in Java. In the latter country there are always small numbers of larvae present on the palms in the regular outbreak areas. In Malaya the pest seems to disappear entirely after an outbreak, the most rigorous search failing to reveal the presence of any larvae at all after an outbreak has terminated. There is, however, one record of the presence of *Artona* in small numbers only on a coconut estate. This occurred in 1936 and is mentioned here because the record appears to have been overlooked. On 15th April 1936, a package containing coconut leaflets attacked by various caterpillars was received and among them were eight larvae of *Artona*. During the period 14th April to 22nd April, six coconut palms, which had been experimentally dusted with lead arsenate against *Chalcoscelis* [Limacodidae], were kept under observation, two fronds being cut from each palm immediately before dusting, four days after dusting and then at two-day intervals. Caterpillars of *Artona* were found on fronds from four of these palms, the total number found on the eight fronds thus examined from each palm being 9, 1, 9 and 27. This estate was visited on 29th April 1936, when three cocoons of *Artona* were found, two of these were empty and the other contained a living pupa. For some reason, observations on *Artona* on this estate then ceased, a most unfortunate occurrence when it is considered that the report was unique for Malaya.

Oryctes rhinoceros (L.) (Coleoptera, Dynastidae)

Before the war, Malaya was comparatively free from serious damage by *Oryctes*. This may be attributed almost entirely to the attention paid to preventing any large-scale breeding. The Agricultural Pests Enactment provided for enforcing the destruction of breeding places but, at least on the majority of estates, it was rarely necessary to invoke the law, the estates themselves seeing to it that large quantities of decaying vegetable matter, which might breed *Oryctes*, were not allowed to accumulate; felled palms were burnt and the timber was removed from new clearings anywhere in the vicinity of coconut estates. In rubber replanting programmes the practice was to fell the trees and either sell them for firewood or burn them on the site, and stumping was frequently practised.

During the occupation of Malaya by the Japanese the situation changed: estates were not maintained in even reasonable condition, there was much felling of timber and *Oryctes* breeding places were created in vast numbers all over the country. The result was an enormous increase in *Oryctes* damage, both to coconut and oil palms.

Since the war there has been extensive replanting of rubber, and in a number of cases rubber has been replaced by oil palms. There has also been replanting of old oil palm areas. Due to the high cost of labour which has prevailed since the war the practice has been, in nearly all replanting programmes, to poison the old stand and underplant with the new crop. In the case of rubber which has been poisoned the tree dies very slowly; the leaves drop after about 3 weeks but this may be prolonged to several months on heavy coastal clays. The branches then begin to fall, shedding pieces from their ends until the bare trunk alone remains, when the trunk starts to disintegrate from the top downwards. It is some 18 months or more, after the application of poison, before any part of the trunk has sufficiently decayed to become suitable for the breeding of *Oryctes*, and it may be another six to eight years before disintegration is complete and no further breeding can take place. Where a creeping leguminous cover is present the decay of the fallen timber is more rapid.

It must be clear, from what has been said above, that the method of getting rid of old stands by poisoning the trees and allowing them to rot, when carried out as part of a replanting programme in which palm trees are in any way involved, is most undesirable from the pest control point of view. The arguments put forward in favour of this practice are low cost and conservation of organic matter in the soil. While the initial cost may be low the ultimate cost is likely to be high: young palms which suffer repeated attack by *Oryctes* are seriously retarded in growth, and they may even be killed; attack on older palms may reduce yields considerably in the case of coconuts, and should the weevil *Rhynchophorus* follow the *Oryctes* attack, death of the palm is almost certain; attack on mature oil palms causes less serious damage but may be followed by *Rhynchophorus*. The cost of control measures may be considerable and is a direct expenditure: labourers must be diverted from normal work to collect larvae; the breeding places created must be destroyed.

Trials have been carried out, both in the laboratory and in the field, with BHC in the form of a dispersible powder as a possible control measure for use against larvae of *Oryctes*. In laboratory trials the larvae were kept in well rotted compost which was watered with a suspension of BHC made up to contain 0·026 per cent. gamma isomer. Two rates of application were used: 32 fl. oz./sq. yd. and 96 fl. oz./sq. yd., the following results were obtained:

Application rate	No. of larvae	Died in 1st–5th day	Died in 6th–10th day	Died in 11th–20th day	Total
32 fl. oz./yd.^{2}	15	1	6	7	14
96 fl. oz./yd.^{2}	15	9	5	1	15
Control	15	0	2	8	10

These application rates would be equivalent in practice to 2·5 lb. and 7·5 lb. gamma isomer of BHC per acre.

In the field the treatment was applied to a sawdust dump in which *Oryctes* was breeding in vast numbers, the adults causing serious damage to coconut smallholdings for several miles. The trouble was caused by a sawmill which was using the sawdust for filling depressions in the ground and as a packing on which to lay a light railway. It was impossible to supervise the application of insecticide in this case and the application rate was therefore set at a high figure in the hope that sufficient would, in fact, be applied to achieve a reasonable degree of control. In practice it was found that the application rate varied from about 40 fl. oz. to 46 fl. oz. per sq. yd. The concentration used was 1 lb. of the dispersible powder (6·5 per cent. gamma isomer) in 4 gallons of water, giving 0·16 per cent. gamma isomer in the working suspension. This would be equivalent to from 19 to 22 lb. gamma isomer of BHC per acre.

Samples of sawdust taken from different parts of the dump were tested for insecticidal activity on *Oryctes* larvae in the laboratory. The results of these tests are given below and suggest a greater variation in application rate than was claimed, though the rate given was adhered to during surprise visits by agricultural officers. There was also a rather rapid loss of insecticidal activity.

Method of BHC application	No. of larvae	Died in 1st–5th day	Died in 6th–10th day	Died in 11th–20th day	Total
3 applications at weekly interval	20	14	2	0	16
1 application	20	16	1	2	19
Control	20	4	0	0	4

Consideration is now being given to the possibility of importing *Scolia ruficornis* F. from Zanzibar. If successfully established it should aid in controlling *Oryctes*, but it is difficult to persuade some planting companies of the necessity for destroying, or at least not creating, breeding places. The practical planter needs no persuading, but in many cases he is controlled by people with inadequate practical knowledge and neither funds nor labour are made available to carry out a thorough clean up campaign.

There seems to be some danger that a successful introduction of *S. ruficornis* might be taken as *carte blanche* for ceasing other control measures.

The range of flight of *Oryctes* from its breeding place to the adult feeding places appears to have been considerably underestimated and is popularly believed to be not more than about 200 yards. So firmly established has this belief become that in one case an estate based its replanting programme on this figure and left a *cordon sanitaire* of 10 chains between the area of poisoned rubber trees and the nearest coconut palms. It soon learnt a costly lesson.

Oryctes rhinoceros has been found breeding in large numbers in poisoned and decaying rubber trunks at least one mile from the nearest coconut palms.

Promecotheca cumingi Baly (Coleoptera, Chrysomelidae, Hispinae)

This beetle was noticed on coconut palms in Singapore in April 1951, and a survey of the affected area was carried out. The following parasites were found:—*Ooencyrtus* sp. (Chalcididae) on egg; *Achrysocharis promecothecae* Ferr. (Eulophidae) on egg; *Dimmockia javanica* Ferr. (Eulophidae) on larva; *Pleurotropis parvulus* Ferr. (Eulophidae) on larva.

Pleurotropis parvulus appears to be the most important in exercising control. There has been no report of any spread of this pest since August 1951, and it is to be hoped that no further trouble will be experienced.

This beetle was previously reported from Malacca in 1917 by Burkill (*Gardens' Bulletin*, **2** (1), 1918) but until the Singapore outbreak there has been no subsequent record of it from Malaya. An article on this beetle was published in *Malay. agric. J.*, **34** (2), 79–82, 1951.

Setora nitens Walk. (Lepidoptera, Limacodidae)

The caterpillar of *Setora* is commonly known as a nettle-grub on account of the urticating spines with which it is clothed. It is most familiar as a pest of coconut palms, but a number of reports of damage to oil palms, sometimes severe and widespread, has been received since the war. In some cases the presence of this insect in pest proportions has continued in a single area for five or more years. Normally, *Setora* seems to be brought under control by biological agencies, the most important probably being the Tachinid, *Chaetexorista javana* B. & B. In a recent outbreak the dominant parasite proved to be the Braconid, *Spinaria spinator* Guer.

In many cases it is not easy to obtain a detailed history of outbreaks which have continued for several years owing to the fact that they are not reported until they have got out of hand. In some cases advice is sought and given, and nothing more is heard about it for a year or two, then information is received that the pest has spread and is causing alarm. In one such instance a report that 800 acres of mature oil palms were being attacked was received. It was claimed that this was an outbreak which had only just started, though all the circumstances suggested that it was of long standing and with a low parasitism. Arrangements were made to lend this estate a power-driven dusting machine, but the offer was refused and the management decided to take no action. Three years later the attack had spread over an area of 2,000 acres.

In another instance, where an outbreak first came under notice in 1948, though it was not reported until much later, approximately 2,000 acres are believed to be involved. The company in question started a dusting campaign using a power duster and a BHC dust of 0·65 per cent. gamma content. This outbreak is known to have been still in progress in 1953, and the explanation appears to be that control measures were never thorough : areas where the attack was heaviest appear to have been dusted but no attention was paid to areas where the attack was less severe.

In a third case, reported in February 1954, it was stated that 500 acres of young oil palms had been attacked. This outbreak was inspected and it was found that *Setora* was heavily parasitised, but another caterpillar, *Orthocraspeda trima* Moore was causing considerable damage and did not appear to be attacked by any species of parasite. In a case of this nature the use of a lead arsenate dust is preferable to a contact insecticide with long residual action because the latter will kill adult parasites while the former will only affect parasites in larvae of *Setora* which are poisoned by it : the presence of a certain number of *Setora* eggs may well result in a recrudescence of this pest if the adult parasite was decimated by the use of a contact insecticide.

The point to emphasise in all these outbreaks is the obvious delay in taking any action. Although the pest was reported as having just appeared, the smallest area affected at the time of the report was 500 acres. That the report coincided with the first notice of the pest is quite possible, for estates do not, except in rare instances, employ " pest gangs " as several of them did before the war.

Parasa lepida Cram. (Lepidoptera, Limacodidae)

This is another " nettle-grub " but no serious outbreaks have been recorded recently. In the only case investigated, in the latter part of 1953, the insect was heavily attacked by *Apanteles parasae* Rohw.

Chalcoscelis albiguttata Snell. (Lepidoptera, Limacodidae)

The gelatine-like larva of this insect does not appear to cause very severe damage of itself but its method of feeding seems to provide conditions particularly favourable to invasion of the fronds by the fungus, *Pestalotia*.

The caterpillars are attacked by several parasites, those identified being :— *Chaetexorista javana* B. & B. (Tachinidae); *Exorista cervinoides* Wulp (Tachinidae); *Sarcophaga krameri* Bottch. (Calliphoridae); *S. orientaloides* S.W. (Calliphoridae); *Systropus roepkei* de Meij. (Bombyliidae); *Fornicia chalcoscelidis* Wilkn. (Braconidae).

One of the most important causes of the termination of outbreaks is a disease which is probably caused by a virus. The rapidity with which the symptoms of this disease develop is remarkable : caterpillars which appear healthy one day collapse and liquify overnight.

Orthocraspeda trima Moore (Lepidoptera, Limacodidae)

Hitherto this insect has been considered of little or no importance but a change in its status may be taking place. In 1952 there was an outbreak of caterpillars of this moth on young coconut palms over an area of about 75 acres. This was brought under control by dusting with BHC (0·65 per cent. gamma isomer) applied with a midget engine-driven duster. In 1954 caterpillars of *Orthocraspeda* were found to be the principal cause of trouble on young oil palms which were reported as being attacked by *Setora*. Some 500 acres were attacked. (See above under *Setora.*) No parasites of *Orthocraspeda* have so far been recorded in Malaya.

Psychidae

There have been no records of the best known Psychid found on palms, *Mahasena corbetti* Tams, causing any serious trouble since the war. There have, however, been several quite severe outbreaks of *Cremastopsyche pendula* Joannis and *Pagodia hekmeyeri* Heyl. A BHC dust (0·65 per cent. gamma isomer) has been found effective, but where attacks are accompanied by *Setora* it is preferable to use lead arsenate in order to avoid killing more parasites than necessary.

PESTS OF CACAO

Helopeltis theobromae Miller (Rhynchota, Miridae)

Helopeltis occurs on cacao throughout Malaya. The most conspicuous damage is that caused to the pods, which develop discrete black spots wherever *Helopeltis* inserts its mouth-parts. The insect appears to be a restless feeder and a single individual will make numerous feeding punctures so that, even where the population is sparse, the number of punctures on each pod is numerous and gives the impression of a heavy infestation. The black spots, if numerous, soon coalesce into irregular black areas of necrotic tissue and the surface of attacked pods becomes scabby, probably as the result of secondary infections. Only very young pods shrivel and die as a result of attack. In older pods the necrotic areas and black discoloration do not extend deeply and the beans appear not to be affected.

A more serious form of damage results from *Helopeltis* feeding on the young shoots. Extensive die-back may follow this type of injury.

Helopeltis theobromae can be controlled by both DDT and BHC applied either as dusts or sprays. The Department of Agriculture normally recommends a BHC dust containing 0·65 per cent. gamma isomer, not because it is superior to other treatments but because such a preparation was readily available when field trials were started, while other formulations were not then on the market in quantity.

A dusting interval of six weeks was found to give almost complete freedom from symptoms of attack, the application rate being 12 lb. of dust per acre on cacao trees 15 to 20 feet in height. There are strong indications, however, that once good control has been established the dusting interval may be extended to as much as 20 weeks and still give effective control.

Alternative hosts for *H. theobromae* so far recorded in Malaya are :—*Bixa orellana, Camellia sinensis, Muntingia calabura.*

Apogonia cribricollis Burm. and *A. expeditionis* Rits. (Coleoptera, Melolonthidae)

These beetles are nocturnal in habits and may cause severe damage to the leaves of cacao, and they also attack many other plants, both economic and ornamental, ranging from herbs to trees. Some details of their habits and remarks on control measures are published in *Malay. agric. J.*, **36** (2), 89–113, 1953.

Until recently it was believed that these two species could be separated morphologically only in the male sex and then only by examination of the aedeagus. It has recently been shown, however (unpublished data of I. J. Wyatt, Entomologist, Department of Agriculture, Federation of Malaya), that both sexes can be distinguished by the following characters :—

Apogonia cribricollis Burm.

(*a*) Head as broad as median length of pronotum.

(*b*) Vertex with unpunctured raised ridge along the margin of the eye.

(*c*) Ridge along posterior margin of head well defined, unpunctured and closer to the thorax centrally than laterally.

(*d*) No punctures in apical third of scutellum.

(*e*) A median depressed line on vertex usually visible when lit from the side.

(*f*) Pygidium usually with a median carina.

Apogonia expeditionis Rits.

(*a*) Head broader than median length of pronotum.

(*b*) Lateral margin of vertex not raised, and punctured up to the eye margin.

(*c*) Ridge along posterior margin of the head not usually well defined, and equidistant from thorax.

(*d*) Scutellum usually punctured throughout.

(*e*) Vertex seldom having a median depressed line.

(*f*) Pygidium usually with no median carina.

Other Lamellicorn Beetles

The Rutelids, *Anomala pallida* F., *Chaetadoretus* spp., and *Lepadoretus* spp. are also responsible for damaging the leaves of cacao. These are dealt with in the reference cited above.

Zeuzera coffeae Nietn. and *Z. conferta* Walk. (Lepidoptera, Cossidae)

The boring caterpillars of these two Cossid moths can cause severe damage. *Z. coffeae* is normally found in the branches, but may also attack the trunk, while *Z. conferta* appears to be confined to the trunk. Attack by the latter can cause the death of medium sized trees.

While the larval and pupal periods of these two insects are known with a fair degree of accuracy, information regarding the oviposition habits and incubation period is still lacking. In confinement the moths rapidly damage themselves and beat their wings to pieces, and oviposition has not been obtained, nor have eggs been found in the field. Knowledge regarding oviposition habits is required before any definite recommendation for preventing attack can be made. Trials of an empirical nature have, however, been started : the basis of these trials being the indication, from reported occurrences of these two insects, that there are probably 3 periods of increase in a year the peaks being in February, May/June and September. Application of a persistent contact insecticide in these months may afford a measure of protection.

At present, the only treatment which can be recommended is to inject a liquid fumigant into the galleries when these are found. From ½ to 1 cc. of o-dichlorobenzene has been found satisfactory, but care must be taken to avoid contact between the chemical and the bark, for this results in necrosis followed by secondary infection.

PESTS OF TEA

Helopeltis cinchonae Mann and *H. bradyi* Waterh. (Rhynchota, Miridae)

Severe damage may be caused to highland tea by these two Mirids and little success in controlling them was achieved until the advent of the synthetic insecticides, DDT and BHC.

In earlier attempts at control, large numbers of Reduviid bugs, common in the lowlands but not present in the highlands, were investigated and those found readily to prey upon *Helopeltis* were transferred to the highlands. A total of 64,000 specimens belonging to six genera and seven species was released on one tea estate in the highlands during 1940/41. Not one of these species was recovered during searches carried out in 1947.

The eggs of *Helopeltis* are parasitised by *Anagrus* sp. and *Erythmelus helopeltidis* Gahan (Mymaridae) and *Telenomus* sp. (Scelionidae).

Of the two insecticides mentioned above, BHC was then only available in quantity as a commercial grade of mixed isomers and was liable to cause noticeable tainting of the made tea. The choice of DDT was therefore a necessity.

After extensive trials in 1947 and 1948 three applications of 5 per cent. DDT dust applied at not less than 30 lb. per acre at intervals of ten days was recommended.

PESTS OF THE CLOVE TREE

The cultivation of cloves and nutmegs has proceeded hand-in-hand in Malaya since their first establishment about 1800. The main areas of cultivation were Penang and Province Wellesley, where a total of some 13,000 acres of cloves and nutmegs was established and bearing in 1860. There were also plantations in Singapore, Johore and Malacca.

It is not proposed to deal with the various causes of the decline of this spice industry in this review, suffice it to say that today there are no plantations in Singapore, Johore, Malacca or Province Wellesley, and the acreage under cloves in Penang Island is negligible, approximately 45 acres consisting of smallholdings.

Chelidonium sp. and *Niraeus tricolor* Newm. (Coleoptera, Cerambycidae)

Two Cerambycid beetles, the larvae of which bore in the trunks or branches of the clove tree, are of major importance. These beetles are *Niraeus tricolor* Newm. and a species of *Chelidonium* which has not yet been described. Field trials with dieldrin emulsion, 1·2 per cent. actual, and gamma BHC emulsion, 0·2 per cent. actual, have given complete protection to treated trees in two successive years while all control trees were attacked. The spray is applied to the trunk and branches and success depends upon correct timing of the operation. Two treatments are necessary, one during the first week or ten days of February and a second during the first week or ten days of March, in cases where both species of borer are present, but in some areas only one of these Cerambycids occurs and it is then possible to dispense with one of the spray treatments.

The concentration of dieldrin used is high, being that found necessary to kill any adult which rested on sprayed bark for a minimum period of 5 minutes, and to remain effective for five weeks from the date of application. In the case of BHC emulsion the concentration is the highest safe one which could be used without scorching the foliage.

It is hoped that it may be found possible to reduce these concentrations considerably and still achieve complete protection against the borers. Experiments along these lines are now in progress. There appears to be some evidence that the effect of these two insecticides in the field may be on the eggs or newly hatched larvae rather than on the adult beetles, sufficient insecticide perhaps being absorbed by the bark to render it toxic to the larvae and thus killing them before they can penetrate to the cambium.

Xyleutes sp. (Lepidoptera, Cossidae)

The larvae of this medium-sized Cossid are white in colour and are frequently confused with the Cerambycid borers by the Chinese clove cultivators. They attack the larger branches, usually of fairly old trees, and are capable of causing quite extensive damage. The insect is not sufficiently common to be considered a major factor in clove cultivation and appears to be confined to a few small areas.

Other insects on Clove Trees

Brief mention may be made of the following :—

Macrotoma fisheri Waterh. [Coleoptera : Prionidae] generally in dead wood but may invade the living tree from the dead portions; *Indarbella disciplaga* (Swinh.) and *Indarbella* sp. nr. *acutistriata* (Mell.) [Lepidoptera : Metarbelidae] the larvae of which make short tunnels in the trunk or in a branch, emerging at night to feed on the bark, which they do under cover of a shelter tube constructed of silk, triturated bark and excreta; *Paralecta antistola* Meyr. [Lepidoptera : Xylorictidae], whose larvae live in tunnels which they bore in the fork of a twig or of a small branch, covering the entrance to their burrow with a mass of excreta woven together with silk, and emerging at night to feed on the bark and probably also on the leaves. Feeding has not been observed, but fresh young leaves are often carried back to the burrow and may be seen embedded in the mass of faecal pellets covering the entrance. A Mirid bug, *Arthriticus eugeniae* Bergr., brilliant red in colour, punctures the young leaves causing a black spot at the site of each puncture and resulting in distortion and shrivelling of the leaf, which subsequently drops off.

There are, in addition, numerous scales and ants associated with the clove tree, but severe attacks of scales have not been encountered.

PESTS OF PINEAPPLES

Dysmicoccus brevipes (Ckll.) (Rhynchota, Coccidae)

This mealybug is of almost world-wide distribution and is found on pineapples in almost all countries where they are grown. *D. brevipes* causes a form of wilt and, while the effects seem to be less serious in Malaya than in some other countries, and less severe in pineapples grown on peat than on quartzite soils, the trouble is quite serious enough to warrant a full time investigation.

In Malaya this mealybug is generally found in greatest numbers round the collar and on the roots of the plant, but it is also present at the extreme base of the leaves and sometimes on the fruit. Pre-war attempts at control with insecticides applied as sprays were not successful, largely due to the difficulty of getting the spray to the insect in the sheltered situation in which it lives.

In 1951 some preliminary trials with parathion were carried out, principally because of claims that this chemical had " systemic " properties. To facilitate examination of the pineapple plants, and also to prevent the mealybug descending to the roots, the plants used in these tests were grown in hydroponic solutions. The parathion formulations used were of unspecified concentration in the case of a dust and a wettable powder, but a water-miscible liquid containing 20 per cent. active ingredient was used at a dilution of 20 cc. in 1 litre. There was no evidence of systemic action but the contact action was good, particularly with the dust.

In 1952, trials were carried out with two formulations of schradan (Pestox 3H* and Tetrax 1†) and with Hanane‡. These insecticides were added to the hydroponic solution in which the pineapples were growing. Results were negative in all trials. It was at first thought that the pH of the hydroponic solution might have some effect on the insecticides, pineapples requiring a rather strongly acid soil, and tests were carried out at different pH concentrations from 3·5 to 7. There was no mortality among the mealybugs in any of these tests.

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* 66 per cent. schradan.

† 70 per cent. schradan.

‡ Bis-dimethylamino-fluorophosphine oxide + schradan 50 per cent. w/w.

Tests with mealybugs on cut pineapple leaves in nutrient solution and nutrient solution plus insecticides gave negative results with schradan, but with Hanane at 1 cc./1. seven out of 27 mealybugs died in 24 hours and at 0·5 cc./1. two out of 27 died in the same period. There were no deaths in the controls.

During these trials it was found that a form of wilt, characterised by incurving of the leaf-margins and shrinkage, accompanied by production of anthocyanin, developed in all plants kept in nutrient solution of pH 7 or slightly more. Five days after the pH was adjusted to 4·5 the leaves started to recover and were completely normal in three weeks.

There is much confusion in the field between mealybug wilt of pineapples and wilt due to water lack from other causes. Anthocyanin is produced in both cases if the plants are growing in sunlight, but in the case of mealybug wilt the colour is bright pinkish-red, while it is purplish-red in cases of wilt from water lack not associated with mealybugs. If a thin strip of epidermis is removed from the upper surface of a wilted leaf, sufficient to remove the layer of cells containing anthocyanin, the underlying tissue will appear white or yellowish-white if mealybugs are the cause of the wilt, but the colour will be green if the wilt is not due to mealybugs. It is presumably the destruction of the chlorophyll which causes the brighter red colour in cases of mealybug wilt.

In varieties which cannot produce anthocyanin, plants affected by mealybug wilt become pale yellowish, but they remain green if the wilt is not due to mealybugs, the difference again being due to destruction of the chlorophyll in the case of mealybug wilt.

The mealybug problem is so intimately connected with ants that measures against these insects must be considered in conjunction with those directed against the mealybug itself. The species of ants so far recorded associated with *D. brevipes* in Malaya are : *Tapinoma indicum* Forel, *Paratrechina longicornis* (L.), *Pheidole megacephala* (F.), *Monomorium floricola* Jerd. and *Tetramorium* sp.

A fair degree of ant control can be achieved with DDT sprays, but there are indications that dieldrin may prove more effective and economical. Aldrin has also proved extremely effective against ants on pineapples but it is not expected to last as long as DDT or dieldrin. None of these has any effect on the mealybug.

It is considered that the use of planting material which is free from mealybugs is essential, but this is not easy to achieve except by fumigation. The only liquid insecticide which has proved entirely effective is aldrin emulsion used as a dip at a concentration of at least 0·24 per cent. actual aldrin and total immersion for quite a long time, at least overnight, is necessary. Other insecticides, even with much longer periods of immersion, have not given a complete kill. [The phosphorus insecticides are excluded from this statement : they have not been tried for dipping purposes and are considered much too dangerous for use by pineapple growers.] Pre-war trials with fumigants showed chloropicrin to be the most satisfactory. Hydrogen cyanide was found to cause damage to both suckers and slips unless they were thoroughly dried. It is hoped to conduct trials with methyl bromide, possibly with a trace of chloropicrin added as a safety precaution against accidental inhalation.

PESTS OF VEGETABLES

Melanagromyza phaseoli (Coq.) (Diptera, Agromyzidae)

This pest can be a limiting factor in the cultivation of beans in both the lowlands and highlands. Its life-history does not appear to have been fully studied in Malaya until 1946. Under laboratory conditions in the lowlands the incubation period is 2 days, larval period 8 days and pupal period 8 days. Eggs may be deposited in the cotyledons as soon as they appear above ground and thereafter they are deposited in the leaf lamina of the true leaves.

Trials were carried out initially with a BHC preparation D. 034, for a sample of which the writer was indebted to Dr. W. S. Bristowe of Imperial Chemical Industries Ltd., who gave this to him early in 1945 for dealing with the hordes of bed-bugs which were such a plague to ones life in the eastern war theatre. So far as is known this was the only sample of BHC, in any form, which was then available in Malaya, though supplies of Agrocide 3 dust (0·65 per cent. gamma isomer) became available not long afterwards.

In the first trials, bean seedlings, and the soil immediately round them, were dusted with D. 034 as soon as the cotyledons became visible above ground, and a second application was made a week later. This gave good control of the pest, only very few plants in the treated plots being attacked. In further trials the addition of a third dusting one week after the second gave complete control.

Phyllotreta sinuata Steph. and *P. cruciferae* Goeze (Coleoptera, Chrysomelidae, Halticinae)

Neither of these common insects appears to have been investigated in Malaya until 1946, probably because market gardeners used derris root as a regular routine treatment on their crops in pre-war years, thus keeping these pests under control. After the war there was a great shortage of derris and what little there was on the market was very expensive. A contributory cause of the increase in these insects may have been the fairly extensive areas under cruciferous crops which was common just after the Japanese surrender. With fairly large areas under a sole crop, damage is more conspicuous than when the cultivation is more varied.

The life-cycles of these two species, not previously having been published for Malayan conditions, are here given :

	sinuata Steph.	*cruciferae* Goeze
Incubation period	3– 4 days	4– 5 days
Larval period	10–14 days	13–16 days
Pupal period	4– 5 days	6– 8 days

A single treatment with a 2 per cent. DDT dust against *sinuata* gave satisfactory control under field conditions but a second dusting about two weeks later may be necessary to kill beetles developing from larvae which were in the soil at the time of the first treatment.

Phytobia cepae (Hering) (Diptera, Agromyzidae)

This onion pest was first discovered at the Naval Base in Singapore in 1951, and was identified through the Commonwealth Institute of Entomology in August 1952. It had previously been recorded only from central Germany, the Ukraine and Japan.

As soon as its presence in Singapore was known, enquiries were made regarding its distribution in that island and it was stated that, so far as was known, it was present only in a small area in which shallots were being grown at the Naval Base. Frequent treatments with BHC, in the form of a dispersible powder in water and as an emulsion based on technically pure gamma isomer, failed to give control and it was suggested that shallot cultivation in this small area should cease for a period of three months, it being explained that the development period from egg to adult averages 19 days in Malaya which, with an adult life of about 2–4 days, brings the total well within the period suggested and gives ample margin for possible delayed development of a few individuals.

Meantime permission was received from the Singapore Government for a detailed survey of all onion and shallot-growing areas in Singapore Island to be carried out by the Department of Agriculture of the Federation of Malaya. This survey showed that a temporary stoppage of shallot cultivation at the Naval Base would have been ineffective because *Phytobia* was found to be present in most onion-growing areas throughout the island. This survey was made in January 1953.

On 4th April 1953, *P. cepae* was found on onions at Kulai and Pandan in South Johore on the mainland and on 23rd May 1953 it was found in large numbers at Serdang, less than 10 miles south of Kuala Lumpur. On 28th July 1953, it was identified at Sungei Buloh 9 miles north-west of Kuala Lumpur.

BHC, aldrin and dieldrin have been tried against this pest but none has proved really successful. Furthermore, the use of insecticides which leave toxic residues on the plants cannot be recommended because of the very short maturation period, only four weeks, of onions in Malaya and because it is the leaves, as much as the bulbs, which are eaten.

When *P. cepae* first became established in Malaya we shall probably never know, nor is it likely that we shall discover whence and by what means of transport it came. Importations of onions into Singapore are mainly from S. India, but small quantities come from Siam, and in both cases they come by sea.

The life-cycle of *P. cepae* bred in the laboratory has been found to be as follows :—

Incubation period	2–3 days
Larval period	4–6 days
Pupal period	11–12 days
Adult life	2–4 days

Adults start laying eggs on the second day after emergence. Breeding is therefore continuous as long as the food-plant is available.

Host-plants so far recorded in Malaya are *Allium ascalonicum* and *Brassica alboglabra*, the latter believed to be the first record from any plant other than some species of onion.

PESTS OF PEPPER

Lophobaris piperis **Mshll. (Coleoptera, Curculionidae)**

The first record of this weevil in Malaya was on 17th June 1953, when samples of damaged vines were received from an estate in Selangor. Although primarily devoted to oil palms and rubber this estate had planted some five acres of pepper. On 4th July 1953, vines showing similar damage were received from Singapore.

This weevil being unknown to us, adults were sent to the Commonwealth Institute of Entomology for identification as soon as they were bred out. Meantime life-history studies were pursued and it was found that, at least with beetles kept in muslin bags on pepper vines grown in pots, there is a period of some four weeks between emergence of the adult and the commencement of egg-laying.

Since the eggs are laid in holes gnawed in the nodes of the vine by the female beetle, and the larva spends its whole life inside the stem, first ringing the node and then boring downwards inside the stem, which it kills, it is clear that the most promising line of attack is some measure designed to kill the beetle after it emerges and before it starts laying eggs. Work on these lines is handicapped by the fact that most of the pepper gardens, where the beetle is known to occur, are situated in Singapore, which is outside the territory covered by the Federation Department of Agriculture.

CUTWORMS

Agrotis segetum **(Schiff.) and** *A. ypsilon* **(Rott.)**

Considerable damage is caused by these pests at Cameron Highlands and in 1952 one or both species were responsible for ring-barking coffee seedlings on the Federal Experiment Station at Tanah Rata.

Dusting the surface of the soil with BHC when sowing, or just before planting out seedlings, has given good results experimentally and is now recommended for field practice where cutworms are a nuisance. In certain cases it may be more economical and equally effective to apply the dust round individual plants. The older method of baiting with a paris green/bran bait four days before sowing or planting out seedlings is also entirely effective when properly carried out.

INSECTS OF MEDICAL AND VETERINARY IMPORTANCE

Flies

House-flies are not, as a rule, a nuisance in the lowlands of Malaya, but both house-flies and blowflies may become exceedingly numerous in the highlands. Why this should be so, at least in the case of house-flies, is not clear, but the comparative absence of ants in the highlands may be one of the reasons. Ants of various species have been observed carrying off *Musca* larvae in the lowlands.

The main sources of house-flies in the highlands are the manures used in vegetable gardens, bean-cake and prawn dust, both exceedingly popular, being perhaps the worst in this respect. These manures are also used in the lowlands and flies certainly breed in them in very large numbers, but vegetable gardens in the lowlands are generally far removed from built-up areas and the flies remain localised with the vegetable-growing. In the highlands, however, vegetable-growing was allowed to spread right through the residential and recreational areas during the war and vast numbers of flies invaded houses and were a menace to health.

Householders were not entirely without blame and many dustbins were found breeding flies, sometimes right alongside the back door of premises owned or occupied by persons most vociferous in protesting about the fly nuisance.

Another prolific source of flies was found to be piles of grass cuttings on a golf-course. Such piles were literally packed with house-fly maggots or puparia.

Except for the vegetable gardens all these sources of house-flies can be eliminated, but there is little that can be done about vegetable gardens unless manures which do not breed flies can be found. The normal method of applying these manures is to place them on the surface of the soil and it has been suggested that their burial in the vegetable beds would prevent fly breeding. Observations show that this is not so. The only remedy, as far as the residential area is concerned, is to prohibit vegetable-growing and the keeping of livestock on a commercial scale in the area. This has now been done, and there has been a marked improvement in the situation.

As regards blowflies, mostly *Chrysomyia megacephala* (F.), the main sources of breeding are pit latrines and liquid pig manure, and there is little that can be done about these except improved latrine design, or water-borne sewage. Deep bore-hole latrines are not generally possible due to the presence of underlying rock.

The foregoing is a very brief condensation of a joint report prepared by the Senior Entomologists of the Department of Agriculture and the Institute for Medical Research in 1952. A publication has since appeared : Bulletin No. 7 from the Institute for Medical Research, Federation of Malaya, Notes on House-flies and Blow-flies, by J. A. Reid (1952).

Hippobosca equina L. and *H. variegata* Wied.

These two flies have been collected in some numbers on Bali cattle (*Bos sondaicus*) imported into Singapore and Kuala Lumpur. When a small breeding herd was established at the Central Experiment Station, Serdang, *H. equina* was found in some numbers on the animals, but not on any other livestock. The flies were apparently completely destroyed by the use of a gamma-BHC emulsion. It seems likely, however, that the vigorous action taken was really unnecessary, for Bali cattle have been imported for slaughter purposes over a considerable number of years, and large numbers were run on estates, as an emergency food supply, just before and during the war, but *Hippobosca* has not become established. All freshly imported Bali cattle searched after the discovery of these flies were found to carry large numbers of either *equina* or *variegata*, many of which deposited puparia shortly after capture, flies being subsequently obtained from these. Despite this there have been no records of these flies on any livestock other than Bali cattle, even when such are kept close to the Bali cattle as is the case at the municipal abattoirs in Kuala Lumpur.

TERMITES

There have been many cases in post-war construction where houses have become termite-infested within a few months of completion, and, although this can hardly be considered an agricultural problem, the Division of Entomology of the Department of Agriculture has been called upon to give advice.

In all cases of damage to new or comparatively new buildings which have been investigated the species concerned have been subterranean termites of the genera *Macrotermes*, *Coptotermes* and *Schedorhinotermes*, and damage has usually first been noticed in built-in furniture or in suspended floors. Entry has been due to faulty construction : cracks in masonry, usually at the junction of floor and wall; timber passing through the cement concrete flooring; badly laid bricks in a wall, the termites being able to pass between the bricks; improperly fitted metal termite barriers, either discontinuous, not projecting far enough, or bent down at too great an angle so that they can be easily bridged, all three faults sometimes occurring together.

It has also been apparent that the eradication of termites from a site before building operations start, and the removal of all tree roots, stumps etc., has not been practised, nor has consideration been given to poisoning the soil of the building site.

The immediate problem was clearly to deal with existing infestations and to devise means of preventing further trouble from subterranean termites, but the question of what measures might be adopted as standard practice in order to minimise the danger of termite infestation in new construction also had to be considered.

Important considerations in nest treatments are that the method shall be easy to apply, that it shall be as nearly fool-proof as possible, that it shall be cheap, and that it shall be completely effective.

The method adopted for applying the insecticide is to bore a hole into the nest with an auger so as to penetrate to the central nursery area and to apply the insecticide through this hole. Details of this method were given to the present writer by Mr. F. J. Gay of the Commonwealth Scientific and Industrial Research Organization at Canberra in general correspondence on termite control, and it is entirely due to the suggestion made by Mr. Gay that this method of applying insecticides to termite nests has been adopted and is now the standard recommendation. In Australia the method is used for the application of finely divided white arsenic, one half ounce being sufficient completely to destroy the nest. Tests in Malaya were carried out with the common mound-building termite, *Macrotermes gilvus* Hag., but it was found that these were not destroyed by white arsenic applied in this way. Various other insecticides were tested by the same method of application and it was found that an aldrin emulsion containing 0·04 per cent. actual aldrin was completely successful, while dieldrin at 0·036 per cent. actual gave very encouraging results. The insecticides tested were as follows :—

Dusts: Calcium cyanide, 42 per cent. $Ca(CN)_2$; BHC, 2·6 per cent. gamma; paris green; arsenious oxide (As_2O_3). One half ounce per nest except in one case of calcium cyanide when one ounce was used.

Liquids: Dispersible powder: BHC, 0·026 per cent. gamma. Emulsions: BHC, 0·02 per cent. gamma; aldrin, 0·04 per cent. a.i.; dieldrin, 0·036 per cent.

a.i.; DDT, 1·0 per cent. a.i.; chlordane, 0·035 per cent., 0·25 per cent., 1·0 per cent. and 2·0 per cent. a.i.; pentachlorophenol, 5 per cent. in a one to four mixture of aromatic gas oil and diesel oil. Rate of application 500 cc. in each case.

The results of these treatments are appended in tabular form (p. 277).

Owing to the difficulty of finding a sufficient number of nests of *M. gilvus* of approximately the same size and strength, and within easy reach of headquarters, the number of these preliminary tests was necessarily limited. The results from aldrin and dieldrin, however, were so encouraging that further work was confined to them. During this subsequent work it was found that dieldrin was quite as effective as aldrin, but required longer to act. In earlier trials, nests had been opened one week after treatment, but dieldrin was found to require about ten days to give a complete kill. The Public Works Department has since reported that they had complete success with the first hundred nests treated with dieldrin.

The actual cost of insecticide for treating a nest is very small, about 0·42 c. for aldrin and 0·39 c. for dieldrin (Malayan currency). Supplies of aldrin are not yet available in quantity in Malaya.

In carrying out these tests it was necessary to use a species of termite which constructs a nest which can be easily found and can also be easily examined, so that results can be assessed in as short a time as possible. Some termite species, however, construct diffuse nests which are spread over a wide area and are not covered by a mound, and when these are beneath a concrete floor or the foundations of a building it may be very difficult to locate them. In certain cases of this kind apparent success has been achieved by breaking open a channel in the concrete where shelter tubes are seen emerging from cracks and saturating the exposed soil with aldrin or dieldrin emulsion. While there is no positive evidence that such treatment has destroyed the colony there has so far been no further termite activity in cases where this treatment has been applied.

The question of soil poisoning has received considerable attention since the Division of Entomology has been consulted on termite problems, but advice on this aspect of termite control can only be based on published information from other countries and it is not always easy to stimulate interest unless facts and figures for local experience can be quoted. The problem at the moment is to persuade those concerned that a treatment which will render the soil beneath a building toxic to termites for a number of years is preferable to one which will only be effective for a number of weeks or months, even if the latter costs only a fraction of the former. Categorical statements about the duration of any particular treatment cannot be made for Malayan conditions because we have no experience. So far, recommendations have been for trials with pentachlorophenol as being likely to give protection over a fairly long period, and some housing sites have been treated with this, using a 5 per cent. solution in a mixture of one part aromatic gas oil to four parts of industrial fuel oil or a 70 per cent. solution of pentachlorophenol in isopropyl alcohol diluted with industrial diesel oil to give a 5 per cent. working solution. The latter, with added plasticizer, has also been recommended for brush treatment of timber which cannot be treated by other means because it is already in place.

An interesting trial carried out with pentachlorophenol was the treatment of the soil for a distance of three feet from the periphery of a mound of an active colony of *Macrotermes gilvus*. A 5 per cent. solution in a mixture of one part of Shell aromatic gas oil to four parts of industrial diesel oil was applied to the soil round the nest at approximately one gallon per square yard (5·5 gallons for 47 sq. ft.). The termite mound, which was about 2 feet in diameter and roughly circular, was not treated. Sixty-eight days after treatment the nest was opened and two small cells containing living termites, mostly workers but a few soldiers, were found in the wall of the mound. These cells did not contain any fungus garden. There were no living termites inside the mound which, except for some empty cells at the base, was hollow.

Experiments in treatments against termites

No.	Insecticide	Dilution rate	Per cent. toxic ingredient	Application rate per nest	No. of nests treated	Result
1	Calcium cyanide	—	42% as $Ca(CN)_2$	½ oz.	2	Not effective.
1a	—do.—	—	—do.—	1 oz.	Repeat on above 2 nests	All termites more than 6 in. from point of application alive. Queen and all termites in central area dead.
2	BHC dust	—	2·6% gamma	½ oz.	2	Not effective.
3	Paris green	—	—	½ oz.	2	Not effective.
3a	—do.—	—	—	½ oz.	Repeat on above 2 nests	Complete kill in one nest. Only round point of application in other nest.
4	White arsenic	—	—	½ oz.	2	Not effective.
4a	—do.—	—	—	½ oz.	Repeat on above 2 nests	Live nymphs in one chamber 1 ft. from centre, all others dead. Only round point of application in other nest.
5	BHC dispersible	1 : 250	0·026% gamma	500 cc.	2. Same nests as No. 2 above	Not effective.
6	BHC emulsion	1 : 500	0·02% gamma	500 cc.	2	Not effective.
7	Aldrin emulsion	1 : 600	0·04%	500 cc.	2	Complete kill in both nests.
8	—do.—	1 : 600	0·04%	500 cc.	2	Complete kill in both nests.
9	Dieldrin emulsion	1 : 500	0·036%	500 cc.	2	Almost complete kill : all survivors moribund.
10	DDT 25% emulsion	1 : 25	1·0%	500 cc.	2	Not effective.
11	Chlordane 70% emulsion	1 : 2000	0·035%	500 cc.	1	Not effective.
12	—do.—	1 : 280	0·25%	500 cc.	1	Not effective.
13	—do.—	1 : 70	1·0%	500 cc.	1	All on same level or below end of bore hole killed. All above this not affected.
14	—do.—	1 : 35	2·0%	500 cc.	1	Complete kill.
15	PCP	—	5·0%	500 cc.	1	Not effective.

Treatments Nos. 1a, 3a, 4a were carried out on the same nests as were used in Nos. 1, 3 and 4.
Treatment No. 5 was carried out on the same nests as used in No. 2.

There were traces of dead termites and a mass of débris resembling disintegrated fungus garden at the bottom of the cavity. It is not suggested that this is a practical method of destroying termite nests, but the result does indicate the effectiveness of soil treatment with pentachlorophenol even in completely exposed situations and under conditions of fairly heavy rainfall.

Trials with dieldrin as a soil poison have also been carried out and an experiment designed to see how long such treatment will last is at present in progress. Boxes of 1 cu. ft. capacity, each with drainage holes in the bottom, have been filled with well-rammed quartzite soil which has then been treated with just sufficient liquid to saturate it without draining from it. Using an 18 per cent. dieldrin emulsifiable concentrate the following four dilution rates have been used: 1: 500, 1: 750, 1: 1000 and 1: 1250. The quantity of fluid required to saturate the soil was found to be 2 litres and all treatments have been found to be toxic to termites. Tests are being carried out at intervals with 15 grammes of soil and 30 termites (*Macrotermes gilvus*) and it is proposed to continue these as long as necessary. Tests with lower concentrations, down to 1: 3000, are just being started.

The lowest concentration used, 0·0144 per cent. actual, represents 0·288 grammes dieldrin per cu. ft. of soil at the application rate used. In practice, to give a depth of penetration of three inches, it would require one gallon of solution per square yard at a cost of approximately 2 c. per gallon.

The Public Works Department has already treated some housing sites with dieldrin emulsifiable concentrate at 1: 1000 with apparently successful results, but lower concentrations have not yet been field-tested.

A test with aldrin, 0·04 per cent. actual, has been carried out against a species of *Nasutitermes* which was attacking a shade tree, ten gallons of the insecticide being applied to the soil for a distance of three feet from the base of the tree and completely encircling it. There has been a complete absence of termites in the soil and on the tree for a period of five months since the insecticidal soil treatment was applied.

No work has been done on wood preservatives as this is carried out by the Forest Department, but various building materials and two samples of underground electric cables, alleged to be resistant to termite attack, have been or are being subjected to graveyard tests.

The termite problem in Malaya is probably neither greater nor less than in other territories where these insects are of importance, but it has probably received less attention in recent years than it deserves. Damage to Government buildings before the war was said to amount to $350,000 per annum or 25 per cent. of the cost of all repairs (Report of Fifth Entom. Conf., 1948, page 103). A more recent estimate (1953) is slightly over $564,000 per annum, but the present writer feels that this is an underestimate.

Summary of Recommendations against Termites infesting Houses

(i) Proper clearing of all timber, tree roots and other cellulose-containing material from new building sites.

(ii) Removal of all scaffolding from the ground, not by cutting it off flush with the ground but by complete withdrawal, and of all timber such as form-boards etc., used during construction.

(iii) Poisoning the soil with a suitable chemical (pentachlorophenol is advised) at least round the foundations.

(iv) No structural timbers to be in contact with the soil.

(v) All timber to be pressure-impregnated with a suitable preservative.

(vi) Attention to the quality of concrete, which is often poor and easily penetrated by termites.

(vii) Attention to the method of bricklaying which often leaves continuous crevices between the bricks due to the improper application of the mortar.

(viii) If buildings are on concrete slabs these should be of such a size that subsidence will not cause cracking and the joints between the slabs should be sealed with bitumen containing 2 per cent. pentachlorophenol and similar seals should be used where vertical piping comes through the canopy.

(ix) Where metal, termite-proof shields are used they must be properly fitted and without breaks in continuity. They should project 3½ inches from the structure they guard and should not be turned down at more than 45°.

(x) Regular inspection schedules should be introduced. No anti-termite measures are completely effective and without inspection they are bound to fail.

ATAP

(Nipah palm thatch)

After the outbreak of the Emergency in Malaya in 1947 a number of military camps was established and, in many cases, these were roofed with atap, a form of thatch made from the nipah palm which grows in coastal swamps. So long as the demand for this roofing material did not exceed the supply there was no trouble, but in 1951–52 several large camps were built, or existing small camps considerably enlarged, and the demand for atap far exceeded available supplies with the result that nipah palm fronds were cut in vast quantities, there was no selection, and the fronds were stitched into atap as soon as they were cut and while still green. The result of this was that in a very short time the roofs of the huts in camps where such atap was used were devoured by caterpillars.

Similar trouble arose under similar circumstances in 1940 and, although investigations were not completed before the invasion and conquest of Malaya by the Japanese, it was clear that the cause of the trouble was intimately connected with the method of preparation of the atap. In the normal preparation of atap only mature nipah fronds are cut and these are put to soak in water, which may be either brackish or fresh, immediately after they have been cut and are left in the water for about one month, though the period varies considerably and may be less than two weeks or as long as six weeks. Atap prepared in this way will last for a considerable time and is not subject to damage by caterpillars.

Investigations in 1940–41 were directed mainly to attempts to control the caterpillars in roofs which were already attacked and to the treatment of atap which had already been supplied but had not yet been used. For this purpose creosote-type wood preservatives diluted with fuel oil were used, but they were not very successful. The use of arsenicals was prohibited by the authorities who feared that the troops would be poisoned.

Meantime, investigations of the insects concerned and their life-histories proceeded slowly. It was found that two species were mainly responsible, *Simplicia caeneusalis* Walk. (Noctuidae), which was by far the more common, and *Herculia nigrivitta* Walk. (Pyralidae). Neither was found on old atap which had been properly prepared nor would the caterpillars feed on it when it was given to them. The inference was that the soaking process removed most of the soluble materials from the leaf leaving only cellulose and lignin, but a full investigation of what actually does happen was not carried out at that time.

This has now been done by the Chemical Division of the Department of Agriculture and it has been shown that soaking the freshly cut leaves for one month removes 83 per cent. of the soluble solids.

When the resettlement programme, in which the scattered rural population was moved into new villages in order to give them protection against the Communist terrorists, was started it was clear that vast quantities of atap would be required for the new houses and a warning about possibility of accepting improperly prepared atap and the damage by the caterpillars of *Simplicia* and *Herculia* was issued by the Division of Entomology. So far as is known there have been no cases of serious damage to atap roofs in new villages where atap has been used, but wherever possible other types of roofing materials were employed.

MAURITIUS

REVIEW OF AGRICULTURAL ENTOMOLOGY DURING THE PERIOD 1948–1954

The Black Sage, *Cordia macrostachya* (Jacq.) R. & S.

The biological control of the Black Sage, a Boraginaceous weed of bushy habit, is the most notable subject to be reported during the period under review. The plant is a native of Central America and the Carribean Islands and is believed to have been accidentally introduced into Mauritius about 1890 from British Guiana. It spread quickly owing to a profuse production of seeds and their dispersion by several species of birds which relished the fleshy fruits. *Pycnonotus jocosus* L. was particularly important in this respect and its association with the plant was so striking that its vernacular name of *Oiseau Condé* was the derivation of *Herbe Condé*, the Mauritian name for the weed. The plant competed successfully with other vegetation and eventually formed a dense scrub on large tracts of uncultivated land at the expense of many useful members of the vegetation. The cost of fibre production from the wild aloe, *Furcraea gigantea* Vent., was considerably increased owing to the difficulty of collecting the leaves, many grazing areas were lost, while the bush was literally a public nuisance because of the coarse nature of its vegetation and its quick invasion of waste plots and untended patches of land.

Ecological studies in Mauritius and in the West Indies indicated that control by the introduction of phytophagous insects was feasible, and with the aid of the Commonwealth Institute of Biological Control the introduction of *Cordia*-feeding insects from Trinidad was begun in 1947.

The first insect to be received, after careful tests for food-plant specificity had been carried out, was *Physonota alutacea* Boh. (Col., Cassididae). Additional feeding tests were made in Mauritius, and upon their satisfactory conclusion the insect was reared in large numbers and released. This introduction, however, proved a failure and *Physonota* did not become permanently established. The reason for its failure is believed to be the susceptibility of the larval stages to interference by various predatory and non-predatory ants, of which the most common on *Cordia* in Mauritius is *Technomyrmex detorquens* Wlk., which feeds upon the plant juices.

A second leaf-eating species, *Schematiza cordiae* Barb. (Col., Galerucidae), had meanwhile been under investigation and, following feeding tests similar to those employed with *Physonota*, the release of laboratory-reared colonies was commenced in March 1948. This introduction proved to be remarkably successful and in the summer months of 1948–49 there appeared extremely large populations of the beetle which caused complete defoliation of extensive areas of scrub. By mid-1950 the sustained attacks of *Schematiza* had caused the death of much of this scrub while severe defoliation was reducing the competitive power of the plant generally.

Late in 1949 a third species, an undetermined *Eurytoma* (Hym. Eurytomidae), which infests the seeds of *Cordia*, was introduced and released. Preliminary feeding tests were unnecessary owing to its specialised mode of life. As with *Schematiza*, the establishment and multiplication of *Eurytoma* was very rapid, and in October 1951 it was causing the destruction of approximately 50% of the seeds of *Cordia* as estimated by fruit samples at or near the numerous points of liberation. Estimates of seed infestation in 1953 showed that on occasions it was as high as 90%, while the average seed infestation calculated from about 25 samples from different localities in February, June and October was 64·6%, 40·8% and 48·7% respectively.

Cordia scrubs have now either completely disappeared, or have been substantially reduced in density in all regions except for a few areas in the south-west of the island. The greater part of this eradication, for which of course only *Schematiza* was responsible, was accomplished within two and a half years of the release of that insect—a surprisingly short time when the previously exhibited vigour and recuperative power of the plant are considered. The quick control was, in fact, unexpected, and those concerned with the project tended to believe that insects which attack the inflorescences and fruits were the most likely to achieve a substantial measure of control. The fact that *Schematiza* controlled the plant without the assistance of other insects must be attributed primarily to its initial prolific multiplication, due to the absence of its many native parasites and the unlimited food supply, and secondly to its suitability to all *Cordia*-infested regions and the lack of interference by the local fauna. Only one entomophagous insect, the Pentatomid *Afrius williamsi* Miller, is known to attack *Schematiza* in Mauritius. The seed-destroying *Eurytoma* became an effective force later, when *Schematiza* was on the decrease; its value is obviously considerable and its action is complementary to the vegetative suppression exercised by *Schematiza.*

Severe defoliation, particularly on young plants, still occurs here and there, but the position has now stabilised, and if further recession of *Cordia* occurs it will be very gradual. It is considered that the present very satisfactory degree of control will at least be maintained owing (*a*) to the reduced competitive power of *Cordia* consequent upon the presence of *Schematiza*, and (*b*) to the reduced rate of reproduction of the plant which results from both vegetative suppression and direct seed attack by *Eurytoma.*

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Sugar-cane White Grub

Severe losses caused by the *Clemora smithi* (Arr.), formerly very frequent, are now seldom encountered. This is attributed chiefly to the replacement of the older susceptible varieties of cane by M. 134/32, a variety which is very tolerant to grub injury owing to its ability to replace roots.

Experiments with BHC were carried out during the period 1947–51. A 20% BHC dust with a gamma isomer content of 2·6% was used at rates up to 100 kg./arpent* and applied to the open furrows when planting and to the soil surface along the cane rows. A lesser infestation, as compared with control areas, always resulted but no significant differences of yield occurred. Phytotoxicity was evident at the higher dosage rates when application was to the open furrows. The conclusion from these experiments was that precautionary application of BHC is not economical in view of the tolerance to grub attack shown by the main cane variety and the inability to forecast the location of a heavy infestation.

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* 1 arpent = 1·043 acres.

In 1949 three parasites were introduced in an effort to supplement the controlling action of the seven Scoliid wasps which had been successfully established in previous years. The parasites were *Dexiomorpha picta* Meig. and *Tiphia morio* F. from Morocco, and *Dexia rustica* F. from England. None has apparently become established. A second attempt was also made in 1950–51 to establish the toad, *Bufo marinus* L. (the first attempt was in 1938), but without success.

Sugar-cane Moth Borers

The following West Indian parasites of *Diatraea* spp. were introduced against the stem borer, *Proceras sacchariphagus* Boj. (Crambidae): *Lixophaga diatraeae* Tns. (1947–48), *Metagonistylum minense* Tns. (1949), *Agathis stigmaterus* Cress. (1949–53), *Prophanurus alecto* Craw. (1950, 1954), *Apanteles diatraeae* Mues. (1951), *Ipobracon* sp. (1953), *Spilochalcis* sp. (1954). None has yet been recovered in the field.

Two parasites were introduced against the pink borer, *Sesamia calamistis* Hmps., formerly known in Mauritius as *Sesamia vuteria* Stoll. The first was *Apanteles sesamiae* Cam., the well-known African parasite of *Busseola fusca*, the maize stalk borer. The introduction was made from Kenya in 1952, and *A. sesamiae* is now established in all regions and a common parasite of the pink borer. The other species introduced was an *Enicospilus* from New Britain, where its host is *S. grisescens*. It was introduced in October 1953 and no recovery has yet been made.

A detailed study of the various parasites which attack cane moth borers in Mauritius was completed and published in 1952 (Moutia, L. A. & Courtois, C. M. Parasites of the moth borers of sugar-cane in Mauritius. *Bull. ent. Res.*, **43**, 325–359, 1952).

Quarantined Cane

Growing imported cane varieties in quarantine is designed to preclude the entry of new diseases into the island, and in this respect it is important that insects which may act as disease vectors do not enter and leave the quarantine greenhouse or breed upon the canes there. This is not so easy to ensure as it may seem.

Experiments with schradan, the systemic insecticide, showed it able to keep cane grown in drums free of Aphids (*Aphis sacchari* Zehnt.) for several months when grown near heavily infested plants. In 1950, subsequent to these experiments, Schradan was first applied to quarantined canes as a routine measure, and since that year no aphid colonies have appeared on such cane, in contrast to previous years when their occurrence was not infrequent. The dose used per 20 gall. drum of soil is 3·0 cc. of the 60% anhydride, or its equivalent, poured on the soil in two litres of water when the canes are 1–2 feet tall. This one application suffices until the next generation is taken about 8 months later.

The Eucalyptus Snout Weevil, *Gonipterus scutellatus* **Gyll.**

The eucalyptus snout weevil apparently entered Mauritius between 1935 and 1940, and by 1944 severe attacks on *Eucalyptus* plantations over the whole island were causing considerable concern. The egg parasite, *Anaphoidea nitens* Gir., which had proved so successful a control agent in South Africa, was imported in 1946. Its establishment and dispersion were rapid and in 1948 it became evident that the weevil was being effectively suppressed. Since that year only sporadic and localised attacks have occurred and the damage caused has not been serious.

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Pests of the Pigeon Pea, *Cajanus cajan* L.

Although a valuable food and green manure crop, the cultivation of the pigeon pea in Mauritius is very restricted, one of the reasons for this being the intense insect attacks to which it is subjected. Investigation showed the following insects to be the important pests—*Maruca testulalis* Gey., *Etiella zinckenella* Tr., *Cosmolyce boeticus* L., *Pardasena virgulana* Mab., and *Cryptophlebia williamsi* Brad. All except *C. williamsi*, which is a gregarious stem borer, attack the pods, while *M. testulalis* also destroys very many flowers.

Preliminary spraying experiments with DDT gave promising results, but as such control measures would be neither practicable nor economic under local conditions, they were not carried further.

It was therefore decided to attempt a reduction of the two most severe of the pests, *M. testulalis* and *E. zinckenella*, by parasite introduction, for neither are inhibited to any apparent extent by natural enemies. The following species were imported from Trinidad in 1953—*Microbracon thurberiphagae* Mues., *Microbracon* sp., *Eiphosoma* sp., *Perisierola* sp., *Phanerotoma* sp., and *Apanteles* sp. Before the close of the pigeon pea season in 1953 the *Microbracon* sp. had been recovered in numbers from *M. testulalis*.

Miscellaneous Introductions of Beneficial Insects

Dirhinus giffardii Silv.

From South Africa in 1949 against the several species of Trypetid fruit-flies in Mauritius. Not recovered.

Cactoblastis cactorum Berg.

The cactus, *Opuntia tuna* Mill., is not very abundant in Mauritius owing to its suppression by *Dactylopius tomentosus* Lam., which was introduced in 1927 from Ceylon. There had, however, seemed to be some increase in its growth for some years prior to 1950, possibly owing to the predatism of *D. tomentosus* by *Cryptolaemus montrouzieri* Muls., a Coccinellid which had been imported in 1938–39 with the object of controlling the pineapple mealybug, *Pseudococcus brevipes* Ckll. As a precautionary measure, to ensure the continued suppression of *Opuntia*, *C. cactorum* was introduced from South Africa in 1950. It is now widespread and bushes are frequently seen collapsing from its attacks.

Pachylister chinensis (Histeridae)

From Trinidad against dung-breeding flies. Introduced in 1950 and again in 1953. Not recovered, but a thorough search for it has not been made.

Stethorus spp. (Coccinellidae)

A red spider mite, *Tetranychus* sp., is a major pest of tomato plantations and sulphur sprays are commonly employed against it. Following the observation that the indigenous Coccinellid, *Stethorus vinsoni* Kapur, is a very active predator of the mite, *S. jejunus* Casey from South Africa and *S. picipes* Casey from California were introduced in 1950 and 1952 respectively. The outcome of these introductions has not yet been investigated.

Cryptochaetum monophlebi Skuse

Introduced from Madagascar against the mealybug, *Icerya seychellarum* Westw., in 1952–53. At the end of 1953 the parasite was well established at the points of liberation but little dispersion had occurred.

NEW ZEALAND

REVIEW OF ENTOMOLOGICAL RESEARCH FOR THE PERIOD 1948–54

Entomological Establishments

Academic Institutions

The four major University Colleges and the two Agricultural Colleges of New Zealand have all increased or are increasing or initiating entomological interest in teaching staff. However, there is still no course in general entomology, there being insufficient demand for professional workers. Nevertheless, it is now possible for students to undertake post-B.Sc. research courses under competent supervision.

Applied Research and " Service " Institutions

With one exception, all are government departmental institutions, and are mentioned below under names of departments concerned.

(i) *Agriculture*

The Department of Agriculture employs only two officers directly connected with entomology. These are a Research Superintendent and his assistant, whose work is entirely concerned with quarantine matters. Entomological research and service in entomology is performed by the Department of Scientific and Industrial Research in close collaboration with field officers of the Department of Agriculture.

(ii) *Scientific and Industrial Research*

(*a*) *Entomological Research Station.*—Headquarters station at Nelson is a combined undertaking with the Cawthron Institute. Staff (apart from clerical) consists of a Director, Senior Entomologist, four Entomologists, and two Technical Assistants at Nelson; an Entomologist in charge, Technical Officer, and Technical Assistant at the Ashburton Sub-Station, and an Entomologist at the Palmerston North Sub-Station. This establishment is at present below efficient strength by two professional, and at least two technical, officers.

The work of this station and its branches is concerned mainly with agricultural problems, and is in close collaboration with the Department of Agriculture. Biological control problems are all conducted under direction of Nelson Headquarters.

(*b*) *Plant Diseases Division.*—The entomological section of this division is situated at Auckland, and is staffed with a Senior Entomologist, two Entomologists, and three Technical Assistants. In addition, two officers are engaged partly in chemical control problems in entomology, one in general therapeutants, the other in timber preservation. The Plant Diseases Division has a strong horticultural bias.

(iii) *Forestry*

Entomological research along both chemical and biological control lines has increased considerably at the Forestry Research Institute, Rotorua. The Forest Pathologist, Assistant Entomologist, and Chemical Control Officer work part or full-time on entomological problems.

Museums

Although there is at present no museum in New Zealand employing a full-time qualified entomologist, such a post is open to be filled at the Dominion Museum, Wellington. Other museums, notably at Christchurch, have staff interested in the improvement of entomological collections and research facilities.

PUBLICATION FACILITIES, ETC.

The following journals are available for the publication of entomological research results and notes in New Zealand.

The New Zealand Journal of Science and Technology (non-systematic technical and research papers); Transactions of the Royal Society of New Zealand (systematic and biological papers); The New Zealand Science Review (general papers); Records of the Canterbury Museum (systematic papers); Dominion Museum Records in Entomology (systematic papers); Records of the Auckland Institute and Museum (systematic papers); New Zealand Journal of Agriculture (articles on control methods etc. of economic insects); The New Zealand Entomologist (Journal of the Entomological Society of New Zealand) (short notes of any description); Zoology Publications from Victoria University College (systematic and biological papers); Tuatara (Journal of the Biological Society, Victoria University College) (notes of various descriptions).

SYSTEMATICS

Although still far from sufficient, it is felt that systematic work has increased in both bulk and coverage over the past few years. It is encouraging to note that in place of the former generation of active amateurs, a generation of equally active young professionals has arisen. The following are the major systematic workers within New Zealand, and the groups in which they are interested:—

Dr. D. Miller (Diptera), Dr. W. Cottier (Aphidae, Coccidae), Dr. J. T. Salmon (Collembola, Tettigoniidae, Phasmatidae, Acarina), Dr. T. E. Woodward (Heteroptera), Mr. E. S. Gourlay (Coleoptera, Strepsiptera), Mr. R. A. Harrison (Diptera), Mr. K. J. Wise (Trichoptera), Mr. D. Spiller (Curculionoidea), Mr. A. Parrott (Ichneumonidae, Braconidae), Mr. B. Given (Melolonthinae, Thynnidae), Mr. L. J. Dumbleton (various groups), Mr. A. E. Brookes (Coleoptera), Mr. J. M. Kelsey (Isoptera), Mr. J. M. Hoy (Melolonthinae (larvae)), Dr. G. H. Satchell (Psychodidae).

In addition to the above, the following groups have received, or are receiving, attention from overseas workers:—

Coleoptera (Carabidae in particular), Diptera (Tabanidae, Tipulidae), Hymenoptera (Formicidae), Hemiptera (Psyllidae), Thysanura.

Absence of systematic activity is notable in the following Orders:—

Coleoptera (part), Hymenoptera (part), Lepidoptera, Odonata, Ephemeroptera, Dermaptera, Perlaria, Hemiptera (part), Orthoptera (part), Neuroptera, Mecoptera.

ECONOMIC PROBLEMS—ENTOMOLOGICAL RESEARCH STATION

Grass-grub (*Costelytra zealandica*, **Melolonthinae**)

The major insect problem in New Zealand agriculture. Control methods have been successfully worked out by the Ashburton Sub-Station of the Entomological Research Station. DDT at a dosage of 1 lb. per acre applied to close-grazed dry pasture with superphosphate gives satisfactory control and several seasons' immunity from attack.

Biological control using wasps of the family Thynnidae from Australia has been attempted, with results not yet known.

Control by the use of nematodes has also been attempted on a restricted scale.

Subterranean Grass Caterpillar (*Oxycanus* **sp., Hepialidae**)

A major pasture pest. Control by use of 2 lb. DDT per acre, or ½ lb. BHC.

Green Vegetable Bug (*Nezara viridula*)

The parasite *Microphanurus basalis* has been introduced, and appears to be exercising satisfactory control where established. Distribution of this parasite is still in progress.

Clover Case-bearer (*Coleophora spissicornis* **and** *C. frischella*)

Attempts at control by use of a parasite complex were attempted, but the handicap of synchronising Northern Hemisphere emergences with diapause host material in New Zealand made the problem a difficult one, and to date no evidence of successful establishment has been obtained.

" Yellow-leaf " Disease of New Zealand Flax (*Phormium tenax*)

Work carried out at Foxton demonstrated the fact that this disease can be transmitted by a native Cixiid, and is probably evidence of the presence of a virus. Control measures by flooding were shown to be practicable.

Fertilisation of Clovers (particularly Red Clover)

Investigations are being carried out with the object of determining whether or not the imported *Bombus* spp. are the major agents in red clover fertilisation, and the relative merits of other agents.

" Manuka Blight " (*Eriococcus* **sp.) on** *Leptospermum scoparium*

The natural appearance and spread (both naturally and by farmers) of what appears to be a new species of *Eriococcus* on the native Manuka or " Tea-tree " have been followed with interest. The biology of the scale is being studied, and a description prepared. The significance of the infestation is that the destruction of large areas of *Leptospermum* in rough country produces the loss of an important factor in erosion control and forest regeneration, but in arable land results in the reduction of what is usually considered to be a weed.

St. John's Wort Control

The use of the Chrysomelid beetle, *Chrysolina hyperici*, has produced spectacular results in certain areas, but it is as yet too early to forecast the permanence of this effect.

Tussock-moth (*Persectania ewingi*)

Experimental work on the control of this pest of native tussock grasslands in the South Island by the use of DDT, BHC, etc. is producing promising results.

Wheat-bug (*Nysius huttoni*)

A study of the biology and life-history of this insect, which sometimes produces deterioration of grain, causing poor flavour and baking qualities in flour, has been carried out.

Sundry Minor Projects

Insect surveys in connection with the introduction of the rabbit virus, myxomatosis, studies of activity and effects on plant roots of Collembola and Symphylids are among a number of less important investigations of a part-time nature.

ECONOMIC PROBLEMS—PLANT DISEASES DIVISION

Timber Pests

Experimental testing of preservatives for use against *Anobium punctatum*, *Ambeodontus tristis*, and *Lyctus* spp. has been carried out, and probably the most important result is in evidence of effectiveness of boric acid solutions.

Physiological experiments on digestion of wood components are being carried out.

Chemical Control of Horticultural Pests and Pests of Stored Products

Below is a list of pest species on which control experiments have been conducted, with the insecticides found to be most satisfactory.

Grape Mealybug (*Pseudococcus maritimus*)	DDT dormant spray and pre-thinning DDT dust applications.
Green Vegetable Bug (*Nezara viridula*)	HETP and DDT.
Apple Leaf-rollers (*Tortrix* spp.)	DDD.
Woolly Aphis (*Eriosoma lanigerum*)	BHC or lindane.
Onion Thrips (*Thrips tabaci*)	DDT sprays.
Potato Tuber Moth (*Gnorimoschema operculella*)	DDT and BHC dusts on stored tubers.
Corn Earworm (*Heliothis armigera*) and Looper Caterpillar (*Plusia chalcites*)	DDD better than DDT.
Apple Leaf-hoppers (*Typhlocyba froggatti*)	DDT.
Mealybugs on Pears (*Pseudococcus maritimus*)	DDT.
Tomato Eelworm (*Heterodera marioni*)	DD and chloropicrin.
Mediterranean Flour Moth (*Ephestia kuehniella*) in pea seed	Chloropicrin.

House-fly (*Musca domestica*)

Tests with space and residual sprays carried out, and recommendations made on the formulations of sprays for New Zealand conditions. Strains resistant to DDT in New Zealand were demonstrated. Tests showed these could be controlled with BHC, chlordane and pyrethrum.

Fruit-fly in imported Oranges

Oranges from South Africa were held in ship cool-stores at low temperatures without damage to fruit, but with complete mortality of the pests. This research made possible large imports of this fruit from South Africa.

Resistance of Plants to Insect Attacks

Physiological studies have been initiated using normal and relatively resistant swedes related to aphid attack. Analysis of leaf constituents and composition of honey-dew produces significant data.

Distribution Surveys

Such surveys have been undertaken on citrus thrips, leaf-rollers of pip and stone fruits, red spider mites on grape vines, and Eriophyid mites on tomatoes.

Fabric Pests

Moth-proofing materials and methods have been investigated, and the biology of carpet beetles and clothes moths studied.

ECONOMIC PROBLEMS—STATE FOREST SERVICE

Applications of chemical control methods by aerial spraying and dusting to forest areas have been attempted.

The biology of the horntail borer (*Sirex noctilio*) has been investigated, and biological control of this pest by introduction of *Ibalia leucospoides* is being attempted.

NIGERIA

REVIEW OF WORK BY THE ENTOMOLOGICAL SECTION, DEPARTMENT OF AGRICULTURE, 1948–1954

Prepared by J. L. GREGORY

Work during the period in question has been concerned mainly with the study of pests of the principal agricultural crops of Nigeria, namely cacao, yams, cereals and cotton, although from 1948 until 1951 a medical problem, that of the *Chrysops* vectors of loiasis, was carried out at the Oil Palm Research Station at Benin.

Cacao pest research has formed a large part of the work of the Section for the last four years because of the urgency of pest problems affecting this crop. Some research work on cacao has been done by the West African Cacao Research Unit, but shortage of staff has only recently permitted the setting up of a permanent substation in Nigeria.

Stored-products pest work has ceased since the institution of the West African Pest Infestation Research Unit.

AGRICULTURAL ENTOMOLOGY

Survey of Mealybug Vectors of Swollen Shoot Disease of Cacao

In June 1951, a survey of the mealybugs occurring on cacao and their parasites and attendant ants was commenced with the object of determining the species that occurred in Nigeria so that further parasites could be introduced to assist in biological control.

Plots were surveyed in each 10-mile square in the cacao-growing areas of Oyo, Ibadan and parts of Benin Provinces and at least 100 trees were examined in each plot.

A total of 18,900 trees were examined up to eye level and 1,183 were found to be infested. From these, 1,293 colonies of mealybugs were recorded comprising a total of 7,168 individuals.

Identification of vector species

The identification of mealybugs was largely based upon a key to the Gold Coast species drawn up by R. G. Donald, Entomologist, W.A.C.R.I., which has since been shown to be of limited value in Nigeria owing to the presence there of *Planococcus kenyae* (Le Pelley). This species, which had not at that time been recorded in the Gold Coast, is of considerable importance in Nigeria and is very close, taxonomically, to *P. citri* Risso. Consequently all the specimens identified as *P. citri* in the survey are referred to as *Planococcus* spp. since, owing to the bleaching of specimens, it is not possible to re-identify the material. Mr. Donald informs me that he has recently identified specimens from 230 colonies of *Planococcus* spp. from Nigeria, of which some 60 per cent. were *P. citri* and the remainder *P. kenyae*.

The survey showed that between different localities there was great variability in the relative proportions of the various species forming the total mealybug population. The actual figures are given in Table I.

Planococcus spp. were the most widely distributed, occurring in all but one locality and comprising some 60 per cent. of the total number of colonies.

Pseudococcus njalensis Laing accounted for 20·5 per cent. of all colonies found. Both this species and *Ferrisiana virgata* (Ckll.) were found in 22 localities, whereas *P. concavocerarii* James and *P. bukobensis* Laing were each recorded from 23 localities.

However, the three species formed much lower proportions of the total number of colonies (6·9, 4·6 and 4·5 per cent., respectively) than did *P. njalensis.*

Despite the relatively low proportion of *P. njalensis* colonies (20·5 per cent.) amongst all colonies found, it is still the most abundant species, forming 45·5 per cent. of the total number of mealybugs, because the number of mealybugs per colony is greater.

In view of the variations which are generally found in mealybug populations on cacao, it would be unwise to place too much emphasis upon the actual figures recorded in this survey. However, it is certain that *P. njalensis* formed a lower proportion of the total mealybug populations than in the Gold Coast, where it comprises 98·9 per cent. of all the mealybugs on cacao (Strickland, 1951).

TABLE I

Relative abundances of the species of mealybug occurring on cacao in western Nigeria

	Number of localities		Maximum percentage of total colonies in one locality	Minimum percentage in a locality when present	Percentage of total colonies	Total number of mealybugs	Number of localities in which dominant
	surveyed	in which species present					
Planococcus spp.	49	48	100	14·3	60·2	3188	39
Pseudococcus njalensis	49	22	95·23	3·22	20·5	3281	8
Ferrisiana virgata	49	22	33·92	2·38	6·9	234	1
Pseudococcus concavocerarii	49	23	33·33	1·78	4·6	100	—
Pseudococcus bukobensis	49	23	21·62	1·96	4·5	164	—
Other species	49	7	14·78	1·96	0·6	58	—
Mixed colonies	49	22	11·10	2·56	2·7	143	—

Planococcus spp. on the other hand are much more important in Nigeria than in the Gold Coast, comprising 60·2 per cent. of total colonies. *F. virgata* is also relatively more abundant than in the Gold Coast.

Attendant ants

Planococcus spp. seem to be attended by all but one of the groups of ants observed to be associated with mealybugs in Nigeria. *Ferrisiana virgata* was found to be ant-attended on only two occasions.

Crematogaster (*Crematogaster*) spp. were found to be the predominant carton makers but three other subgenera of *Crematogaster* and two other genera were also found to make cartons for *Planococcus* spp., as were three subgenera of *Crematogaster* for *P. njalensis* and one each for *Pseudococcus concavocerarii* and *Pseudococcus bukobensis.*

Parasites and predators

The most important predators of mealybugs of cacao in Nigeria appear to be various unidentified species of Cecidomyiid midges which accounted for 91 percent. of the total predators reared and were associated with colonies of *Planococcus* spp., *P. njalensis*, *F. virgata*, *P. bukobensis* and *P. concavocerarii*. Coccinellidae, principally *Scymnus* spp., were also important, being found attacking all species of which more than 500 specimens were collected, namely *Planococcus* spp., *F. virgata* and *P. njalensis*.

The principal parasites were *Leptomastix bifasciatus* Comp., and *Neodiscodes martinii* Comp., which comprised 86·4 and 7·5 per cent., respectively, of all the primary parasites collected. Both these parasites attacked *Planococcus* spp. *P. njalensis*, *F. virgata* and *P. bukobensis*, the principal mealybug species. Several species of *Anagyrus* were also found attacking these mealybugs. A hyperparasite *Cheiloneurus carinatus* Comp. was abundant.

A species of *Aspergillus* was recorded attacking *Ferrisiana virgata.* Females of this mealybug were collected on sprouting potato tubers and inoculated with spores from a pure culture of the fungus. A large proportion of mealybugs in the treated colonies were dead within six days and the dorsum was enveloped with sporulating hyphae.

Cacao Capsid

Work on the Capsid pests of cacao has been directed principally towards obtaining a safe and economical method of protecting mature cacao trees from these insects and also of aiding the recovery of badly damaged cacao by allowing it to proceed unhindered by further attack. Some biological data were also obtained.

Table II shows the relative abundance on pods and other feeding sites of the three species of Capsids over a period of 29 months at 9 stations. *Sahlbergella singularis* Hagl. was observed more frequently than either *Distantiella theobroma* (Dist.) or *Helopeltis bergrothi* Reut. *H. bergrothi*, on the other hand, shows a marked preference for pods and its feeding lesions are rarely seen on vegetative parts of the plant which are readily attacked by the other two species.

TABLE II

Distribution of Capsid populations by species and part attacked

Species	Pods			Vegetation			Species total	
	Numbers	Percentages		Numbers	Percentages		Numbers	Percentages
		By site	By species		By site	By species		
S. singularis	37184	45·8	84·8	44016	54·2	92·3	81200	88·7
D. theobroma	2432	45·7	5·5	2887	54·3	6·0	5319	5·8
H. bergrothi	4251	84·2	9·7	796	15·8	1·7	5047	5·5
Site totals	43867	—	100·0	47699	—	100·0	91566	100·0

In general, relatively small numbers of Capsids are found on cacao, and leaf blast frequently occurs when only 25–40 per 100 trees are found to be present, using the counting technique described below.

Methods

Experiments began in September 1951 to determine the effect of insecticidal dusts upon Capsid populations, the amount of damage caused by Capsids and on the numbers of pods produced.

Eight two-acre plots were chosen in different localities situated in the main cacao-producing areas of Nigeria. Half of each plot was treated with insecticidal dust and the remainder was untreated.

Care was taken to choose pairs similar in vegetative appearance, soil type and Capsid populations at the outset. In case of slight dissimilarities, the half-plot in better vegetative condition was designated as control.

In each plot a minimum of 100 trees was selected at random and observations were made from ground level to 18 foot with the aid of ladders. Estimates were made at ten-day intervals of the population of each species, on pods and branches, Capsid damage and the number of green pods on the tree.

On four of these eight paired plots a 5 per cent. DDT dust was used and on the other four a 0·45 per cent. BHC dust. No significant difference was found to exist between the effects of the two insecticides, and as the BHC dust was found to irritate the operators, its use was subsequently discontinued.

Dusting in 1951–53 was by knapsack dusters powered by small petrol motors. The initial rate of application was 40 lb. per acre but was later reduced to 20 lb. per acre.

In 1952, dust was applied six times at 35-day intervals commencing at the end of August and ending in mid-January 1953.

It became evident that the lowest densities of *S. singularis* tend to occur in May-July. Therefore, dusting in 1953 began in the first week of July and was repeated later when the Capsid population reached 25 per 100 trees. In only two plots were more than three treatments necessary. These plots were severely damaged and required seven dustings. The Capsid populations in three plots were kept below the level of serious damage by only two applications of dust.

Results

There was always abundant visual evidence of improved vegetative condition associated with treatment, in contrast to the continued damage in the untreated cacao nearby. There is an association between numbers of Capsids and estimates of damage. Significant correlations were found between monthly moving averages of leaf-damage scores and of number of Capsids when log. transformations were applied.

Significant reductions in Capsid populations were obtained following each dusting, and populations in the treated plots were kept down to levels at which little damage occurred.

Protection of mature cacao has been achieved with three dustings per year except in areas of severe attack where as many as eight or nine applications were necessary.

Consistent improvements in yields, as estimated by the number of green pods, were not evident until 15 months after dusting had begun. The increase in yield of treated plots as compared with their controls corrected for differences observed in the first six months range from 5 per cent. to 44 per cent. It should be borne in mind that a control plot may continue to deteriorate while a treated one is improving in condition. At the present time, after 27 months, these increases are being maintained consistently.

The cost of each application is estimated to be about 18/- per acre, of which the cost of dust comprises 67 per cent. and cost of transport and operating 33 per cent.

Other insecticidal trials

An attempt was made to incorporate DDT emulsion concentrate into the carbide-bordeaux spray used against black pod disease. This gave a significant control over a seven-month period during which spraying was carried out every 35 days and for two months after the last treatment. But the level of control achieved using this spray was not nearly so good as that achieved using the DDT dust, because spray was applied to pods for black pod disease control.

A DDT aerosol was tried against cacao Capsids but gave no significant reduction in populations.

Shot-Hole Borers of Cacao

Davey (1948) reported that F. D. Golding had observed the Scolytid, *Coccotrypes pygmaeus* Eichoff, attacking cacao seedlings at Ibadan in 1944.

In the dry season of 1949–50 considerable losses occurred on young seedling cacao plantations in the Western Region of Nigeria and the deaths were frequently associated with the presence of shot-hole borers to which they were at the time attributed. Consequently, studies of the biology and control of these beetles were begun.

Infestation by the beetles tended to follow upon unfavourable conditions for plant growth. The most important factor appeared to be drought, since the infestation was rare or absent in the wetter months of the year. In an experiment on a small shaded plot of cacao seedlings in the dry season of 1951, considerably more deaths occurred when the seedlings were watered weekly than when water was given daily.

Subsequent study of the shot-hole borers of cacao revealed the presence of 11 species of Scolytidae and three of Bostrychidae. Of these, all but four Scolytidae were only recorded attacking dead cacao tissue and will not be considered further.

The species previously referred to as *C. pygmaeus* Eichoff was re-identified by Professor Dr. K. E. Schedl in 1953 as *Xyleborus morstatti* Hag. which is of widespread occurrence on cacao seedlings in West Africa.

Four species may be concerned in attacks upon live wood. Two of these, *Stephanoderes solitarius* Schedl and *Stylotentus ater* Eggers, attack only tissues which are unhealthy or dead, and two, *X. morstatti* and *Poecilips confusus* Eggers have been recorded attacking live healthy wood.

Stephanoderes solitarius and *Stylotentus ater* are similar in habits and method of attack and may be considered together. The point of entry is usually, though not invariably, at a leaf-base or scar tissue, and the beetle bores radially inwards to the centre, where a small cavity may be formed. Here eggs are laid and boring by the larvae and adults proceeds through the wood along the main axis of the seedling. Fungal growth has occasionally been observed in *S. solitarius* galleries. Cacao is the only plant known to be attacked by these species.

Poecilips confusus attacks live seedlings and the method of attack appears to be similar to that of *X. morstatti.* It is comparatively rare, and little is known about it.

Xyleborus morstatti

X. morstatti is the most important of the shot-hole borers attacking cacao seedlings.

The gallery is made by a single female, entry typically taking place on the smooth surface of the bark, not at a leaf-base. The gallery extends radially into the centre of the seedling where a rounded brood chamber is excavated.

The thickness of the wood of attacked stems usually varies from $\frac{1}{8}''$ to $\frac{1}{4}''$, although instances have been recorded where *X. morstatti* has attacked plants as small as $\frac{1}{16}''$ and as large as $\frac{3}{4}''$ thickness of wood. The height at which the plant is attacked varies considerably, the point of entry is commonly between $2\frac{1}{2}''$ and $12\frac{1}{2}''$ from the ground. This range is probably related to stem thickness.

A batch of about twenty eggs is laid in the first two or three days, after which the rate of egg-laying falls off rapidly. The number of young produced by a single female varies considerably. In the cases of 14 chambers of *X. morstatti* containing pupae or young adults, the number of progeny ranged between five and 54 with a mean number of 29·4.

The larvae are a milky white colour and their gut contents are never darker than the rest of the body, in this respect the larvae differ from the other Scolytids which feed on wood and pith of the cacao seedling.

The average ratio of males to females for 163 beetles is 1 : 4·6 but in individual galleries this ratio has ranged between 1 : 1·5 and 1 : 9.

The length of the life cycle is not known because attempts to rear the insect through from adult to adult have not yet succeeded, largely owing to the difficulty of feeding the larvae. The duration of the egg and pupal stages are approximately five, and six to seven days, respectively.

The ' ambrosia fungus '

In the early stages of development of the brood chamber a white fungus layer about 1 mm. thick is visible on the walls of the chamber. It is probable that this layer contains an ambrosia fungus, but cultures of the fungus have not given conclusive results.

Pieces of mycelium from three galleries have given rise to the fungus *Botryodiplodia theobromae*, twice from *X. morstatti* and once from *S. solitarius* galleries. This fungus commonly occurs as a weak parasite of cacao in Nigeria. It is possible that it is present as a contaminant of the ambrosia fungus which may not grow in the culture medium used.

If *Botryodiplodia theobromae* does play a part in the nutrition of the beetle it would appear that the spores are not carried on the surface of the beetle. In 13 tubes where *X. morstatti* adults were removed from fungus-infected chambers and allowed to crawl on the culture medium, no *Botryodiplodia* developed.

It is interesting to note that Gowdey (1918) reported that ' *Xyleborus camerunus* Hag. attacks cacao, but caused death only in those plants already infected with the fungus, *Diplodia* '.

Damage caused to cacao seedlings

The wood immediately surrounding the brood chamber and for a distance of about half an inch above and below it is stained a dark brown colour. Death of the plant often occurs ½″ to ¾″ below the entrance hole of the beetle, the dividing line between the live and dead portions of the wood being very sharp.

The presence of *X. morstatti* in a seedling is often indicated by a swelling or a shrinking of the stem around the brood chamber. The shrinking of the wood begins just below the point of entry and is due to the shrinking of the bark subsequent to its death. The cause of the swelling, which occurs occasionally in the wood, is not known.

Additional damage to seedling cacao is often caused by the entry of secondary fungi into borings caused by the Scolytids and such infection is one of the major causes of seedling death.

Control experiments

Attempts to prevent death of seedlings by the use of insecticides applied by hand to cacao seedlings have given little information of value. This lack of success is partly due to environmental conditions having a greater effect upon seedling death than has Scolytid attack, and partly to the small numbers of seedlings available for trial under field conditions.

TABLE III

Effect of insecticides on entry of Scolytids into seedling cacao

Insecticide	Actual concentration %	Percentage twigs undamaged	Colonies per 100 twigs	Dead Scolytids and empty galleries	Live and breeding colonies
DDT emulsion concentrate (A)	2·5	70	37	8	3
Aldrin emulsion concentrate	1	65	48	10	19
Dieldrin emulsion concentrate	1	83	17	9	1
Endrin emulsion concentrate	1	88	12	3	4
DDT emulsion concentrate (B)	2·5	83	17	4	1
Control	—	12	158	21	74

Experiments have been designed to test the effect of insecticide applied to twigs of mature cacao trees. One twig, 12″ long, was stripped of leaves and broken from each of a number of cacao trees. Each was then tied onto the tree, painted with one of several different insecticidal solutions at various concentrations and left for ten days. At the end of this period, the twigs were dissected and the number and condition of Scolytid galleries was recorded. Results for the best concentration of each insecticide solution are given in Table III.

Endrin was the most effective in preventing Scolytid entry and dieldrin in preventing breeding. Endrin is preferable because it is desirable to prevent entry in order to minimise the harmful effect of secondary fungi.

Cereal Stem-borer Survey

In 1951 and 1952, a survey was made in the Northern Region of Nigeria to determine the rate of attack by stem-borers of cereal crops.

Approximately that part of Northern Nigeria which lies north of the 9° N. Lat. was surveyed in the first year and the area south of the line in the second.

The area covered in 1951 contains the whole of those parts of the Sahel vegetational zone and the greater part of the Sudan and Northern Guinea zones which occur in Nigeria. The Nigerian parts of the Southern Guinea, Bauchi Plateau and Derived Savannah zones and part of the Northern Guinea zone were surveyed in 1952. Details of the vegetational zones are given by Keay (1952).

Observations were made at villages at approximate distances of every 20 miles along all motorable roads. One hundred plants were inspected at random in one field in each locality and any holes in the stem were opened. Borer larvae collected were preserved for later identification. Pupae were kept for rearing to the adult stage, but it was difficult to maintain conditions suitable for emergence while moving from place to place and adults did not emerge from some of these.

Only 30·2 per cent. of the total number of borer holes contained larvae or pupae and only 19·6 per cent. were identified, so that too much reliance should not be placed upon the figures of percentage infestation for each species.

Total infestation rates

Infestation rates observed in the survey are shown in Table IV. In 1952 the average proportion of guinea-corn plants attacked by stem-borers did not differ greatly from that of 1951.

TABLE IV

Percentage stem-borer infestation rates of the major cereals of Northern Nigeria in 1951 and 1952

	Guinea corn	Millet	Maize	Rice	Sugar-cane
Number of localities	149	108	20	51	24
Average 1951 infestation	29·18	31·21	13·33	30·16	8·6
Average 1952 infestation	28·6	27·0	24·13	21·69	22·0
Minimum infestation rate	2	5	6	8	9
Maximum infestation rate	78	64	25	31	28
Average for the 2 years	28·93	29·96	21·95	22·69	19·17

The infestation rates for the other crops in 1952 differ from those obtained the previous year. Owing to the low relative importance of these crops only a few samples could be taken. In 1951, six samples of rice were taken, five of sugar-cane and four of maize, as opposed to 45, 19 and 16, respectively, in 1952. The figures obtained in 1952 are estimates nearer to the actual infestation rates.

Species attacking crops

Seven species of borers were found attacking cereals in the survey, namely:

Pyralidae	*Chilo ignefusalis* Hamps.
	Eldana saccharina Walk.
	Chilotraea sp.? *africana* Auriv.
	Sylepta balteata F.
	Rhinaphe vectiferella Haw.
Noctuidae	*Busseola fusca* Fuller
	Sesamia calamistis Hamps.

Table V shows the numbers of stem-borers found and the infestation rates over the two years on a basis of 100 localities, to make the results for each crop comparable.

TABLE V

Number of each stem-borer species attacking cereal crops per 100 localities

	Actual number of localities surveyed	*Chilo*	*Busseola*	*Sesamia*	*Eldana*	*Chilotraea*	*Sylepta*	*Rhinaphe*
Guinea corn	149	177	324	131	90	—	—	—
Millet	108	382	44	36	110	—	—	—
Maize	20	35	185	465	55	—	—	—
Rice	51	6	—	6	14	2	2	14
Sugar-cane	24	4	4	13	—	—	—	—
Total		604	557	751	269	2	2	14

Thus *Chilo ignefusalis*, *Sesamia calamistis* and *Eldana saccharina* have been found to attack all the cereals surveyed, and *Busseola fusca* all except rice. Three species, *Sylepta balteata*, *Rhinaphe vectiferella*, and *Chilotraea* sp. nr. *africana*, were only found on rice.

Small numbers of three other cereals, achcha (*Digitaria exilis*), aburu (*D. iburua*) and tamba (*Eleusine coracana*) were also examined. *C. ignefusalis* was recorded on aburu, and *B. fusca* and *S. calamistis* on tamba. In five localities (500 plants) no borer infestation was recorded on achcha.

An interesting point is the marked dominance of *C. ignefusalis*, *B. fusca* and *S. calamistis* among borers of millet, guinea corn and maize respectively. The number of each of these species recorded on the crop mentioned, as a percentage of the total number of that species on all crops, is 63·3, 58·2 and 61·9, respectively.

Survey by vegetation zones

The number of observations on maize, rice and sugar-cane was small. Consequently, no conclusions could be drawn about the differences in borer infestation rates between crops in different vegetational zones.

B. fusca was dominant on guinea corn in all but one of the vegetational zones, although in the Derived Savannah and Southern Guinea zones, *S. calamistis* was almost as common as *B. fusca*. In the Sudan zone *C. ignefusalis* formed 64 per cent. of the total identified population, *B. fusca* was next in order of abundance (17 per cent.).

C. ignefusalis was the most important borer of millet found in three vegetational zones, the Sudan, Northern Guinea and Derived Savannah, *S. calamistis* in the Bauchi Plateau and *E. saccharina* in the Southern Guinea. *E. saccharina* generally came next in order of importance as a borer of millet.

Control of Maize Stem-borers

The principal stem-borers which attack maize at Ibadan are *Sesamia calamistis* and *Busseola fusca*. The former is the more important, comprising some 70 per cent. of the total number of borers, while the latter accounts for most of the remainder. *Argyroploce leucotreta* Meyr. is also present but is comparatively rare.

A series of five experiments was begun on the late crop in 1951 in an attempt to find an economical method of controlling these pests. These experiments were designed to compare the effects of various insecticides upon yield and borer infestation.

A randomised block layout was used with 12 replications of six treatments. Each plot was split into three subplots which were sown at intervals of 14 days.

The variety of maize used was Lagos White, one of the most widely planted varieties in Southern Nigeria but one which does not give very high yields.

The insecticides were applied to young maize plants (about 30″ high) until run-off occurred from all leaf axils.

After a preliminary trial on the late crop of 1951, similar results have been found in four subsequent trials in which layout and treatments were the same. Results from the experiment on the late maize crop of 1953 are summarised in Table VI.

TABLE VI

Results of experiment on control of stem-borers of maize: Ibadan, 1953

Insecticide	Concentration of insecticide %	Yields in lb. per acre	Percentage of nodes infested	Percentage of plants attacked	Yield in lb. per acre at 2nd planting date
Aldrin	0·084	401	4·18	23·54	506
Dieldrin	0·26	401	4·26	22·78	504
Endrin	0·057	385	3·37	19·40	456
BHC	0·0094	330	4·87	24·02	417
DDT	0·05	349	4·47	23·48	461
Control	—	321	5·02	23·24	455
Mean	—	364	4·36	23·24	455
Significant difference at 5 per cent.	—	45·3	1·00	4·01	43·9

In this experiment, the yields from plots treated with aldrin, dieldrin and endrin were significantly greater, and the infestation rate of plots treated with endrin was significantly less than those of the control plots.

Yield differences caused by treatments tended to be obscured by the much greater differences due to different planting dates. The yields at the optimum planting date showed greater proportional and absolute differences due to treatments than did the mean yield for the three planting dates. In the experiment cited above, the yield of all aldrin-treated plots was 80 lb. per acre (24%) greater than that of the control plots whereas there was an increase of 117 lb. per acre (30%) over the controls when only subplots of the best of the three planting dates are considered.

Over the whole series of experiments, plots treated with endrin generally gave the highest yields, closely followed by those of aldrin, dieldrin, DDT and BHC in that order. Treatment with Arkotine and Liquid Agrocide 3 resulted in slightly higher yields than those found in control plots.

Endrin has been consistently the most effective in reducing stem-borer damage, the differences being significant at the 1 per cent. level.

In general, the increases in yield following the use of insecticides as applied in these experiments were not economical at this level of stem-borer infestation.

It is possible that the effect of borer control on some of the higher yielding varieties of maize might give economical returns, particularly in the late maize crop which is usually more heavily infested than the first.

Yam Beetle Control Experiments

In 1950–1952, a series of experiments was carried out in an attempt to find a simple but effective method of controlling damage caused by yam beetles (*Heteroligus meles* Billb. and *H. appius* Burm.—Dynastidae).

In April 1950, a small-scale trial was set up to test the efficiency of five treatments, namely: 0·45 per cent. gamma BHC dust and 5 per cent. DDT dust, applied either as a ‘ seed ’ dressing to the yams at planting time, or on top of the hills immediately after planting. Another treatment was the application of an oil-palm fibre mulch to the yam hills immediately after planting. The amount of insecticide applied was ½ oz. per hill and as a dressing was approximately ⅛ oz. per ‘ seed ’. The results are given in Table VII.

TABLE VII

Results of Yam Beetle control experiment, 1950

Treatment	Control	5% DDT dust on hills	Agrocide 2 (BHC) dust on hills	Oil-palm fibre mulch	5% DDT dust seed dressing	Agrocide 2 (BHC) dust seed dressing
Yield in lb./acre	4817	4269	4526	5933	4458	5064
Percentage yams damaged	91·1	78·9	77·8	73·3	80·0	35·6

It would appear that the application of an oil-palm fibre mulch induced an increase in yield over that of the control plots of approximately 23 per cent., although it did not lower the yam-beetle damage rate greatly. Also following the use of the BHC dust applied to the ‘ seed ’ yams before planting, the percentage of yams damaged decreased from 91 to 36 per cent., resulting in an increase of approximately 5 per cent. in weight. No significant correlation between yield and rate of attack was observed.

There was no statistically significant evidence of difference between the yields of the other four treatments, but it appeared that BHC dust was more effective in controlling yam beetle than is DDT. It was better to apply the insecticide to the ‘ seed ’ yam before planting than to the hills immediately after planting.

Four other experiments in 1950 and 1951 confirmed these conclusions but the low level of yam-beetle attack in all experiments (the control plots had overall attack rates varying from 3·9 to 17·5 per cent.) caused yield increases to be proportionally less than in the first experiment.

In 1952, the effect of seed wash (dipping ‘ seed ’ yams in insecticidal suspensions) was compared with that of seed dusting and was found to afford better control. The difference between the number of yams attacked in the treated and control plots was statistically significant although there was a very low overall rate of attack (3·9%) in this experiment.

Tests have been made to determine whether the insecticides have any adverse effect upon the taste of the yams and none has been noticed at the rate of application used, which is about ¼ oz. per yam.

In the original experiment cited above, attempts were made to determine the amount of yam eaten by the beetles by filling the holes with plasticene, removing and weighing it. In no treatment was the loss in weight more than 5·2 per cent. of the total weight of the yam (corrected for the different specific gravity of yam and plasticene).

No correlation has been obtained in any experiment between yield and rate of attack. This is probably because of the small loss in yield caused by this pest. It is highly unlikely that insecticidal treatment would be economical where only weight considerations are of importance, except in very heavy infestations. However, where the appearance of the yams is important in determining their value, then it may often be economical to use chemical control measures.

Sorghum Midge

In January 1953, a number of Cecidomyiid midges emerged from heads of guinea corn from Ibadan and these have since been identified as *Contarinia sorghicola* Coq. It was the first record of this pest from Nigeria.

Subsequently, Cecidomyiid midges have been collected from nine different graminaceous host-plants from 28 localities throughout Nigeria. Identifications have not yet been completed, but at least three and probably more species of midges (one of which is *C. sorghicola*), belonging to widely separated genera, have been recorded.

MEDICAL ENTOMOLOGY

Chrysops spp.

In the years 1948–51, work on the biology of the *Chrysops* vectors of loiasis was continued at the Oil Palm Research Station near Benin in Southern Nigeria.

The results of the work have been published (Davey & O'Rourke, 1951, a, b and c) and the following is a summary of these papers.

The species of *Chrysops* occurring at Benin which are known to transmit loiasis were *C. dimidiata* Wulp and *C. silacea* Aust. *C. dimidiata* was the more common, comprising some 67 per cent. of the total number of flies captured during four years. *C. longicornis* Macq. also occurred at Benin, but the only specimens seen were those reared from larvae obtained from the banks of the Okhuo river.

Most of the adult *Chrysops* were found in clearings near to the river in close proximity to the breeding grounds. In the forest, away from the river bank, *Chrysops* was rarely taken, though it may be present in the canopy. It was certainly taken in the canopy near to the river but it was not possible to sample the canopy at any great distance from the river. Captures in houses away from the river represented only a small proportion of the total catch.

No male *Chrysops* has been taken in the field although the sexes bred out in approximately equal numbers from larvae brought to the laboratory.

Chrysops was abundant from about the end of May until the beginning of November, *i.e.*, during the rainy season, and probably occurs in very small numbers throughout the rest of the year. The density was low until April or May when it rose steadily to a peak in the latter half of the rainy season and then fell off as the rains decreased.

C. silacea was usually present in small numbers in April or May after which the population rose to a peak in July or August when it normally became the dominant species. The numbers then declined rapidly and by October it had almost disappeared.

C. dimidiata either appeared early in numbers equal to *C. silacea* or much later as in 1946 when the first specimen was taken on September 19th. When it appeared early, the population decreased in July or August and then increased rapidly to a peak in October when it constituted up to 90 per cent. of the total *Chrysops* caught. A steady decline in numbers then followed through November.

Chrysops appeared to bite between 7 a.m. and 6.30 p.m. and bites were rarely recorded outside this time. Labourers working in clearings along the Okhuo river were frequently bitten up to midday. When the temperature reached a maximum in the early afternoon, the flies retreated into the shade of the surrounding forest from which they continued to attack labourers working in the immediate vicinity.

The flies were generally persistent, the ankles and lower parts of the legs being the parts most commonly bitten.

Cattle were attractive to the flies but sheep were not. Collections with cattle as bait were higher than those made in the absence of cattle although the flies tended to feed on the humans present rather than upon the cattle themselves.

The largest numbers of flies were taken where gangs of labourers were working and it is possible that attractiveness may be due to size and movement of the object.

The flight range of *Chrysops* was studied by the liberation and recovery of flies marked with an aqueous solution of methylene blue. The longest distance recorded between the place of liberation and that of capture of eight flies from a total of 557 released was 1,200 yards but some evidence existed that they may fly further.

After sampling various other possible breeding sites, searches were finally concentrated along the banks of the Okhuo river. Following the rearing of two adults of *C. dimidiata* from larvae recovered from mud along the banks in 1947, *C. silacea* and *C. longicornis* were also found to breed in the same habitat.

Breeding was confined to densely shaded places where the banks were swampy and where there was a thick mass of decaying vegetable matter over the mud. Where the edges of the river were clear and sandy, no larvae were taken.

In the mud, larvae appeared to be confined to places where there were large amounts of decaying vegetable matter and not more than one inch of standing water. In fact 94 per cent. of all Tabanid larvae were recovered from the damp and saturated mud at the edge of pools. No larvae were found below three inches depth of water.

The pH of 50 water samples varied between 4·3 and 5·2 but the distribution of larvae appeared to be independent of the acidity.

The average length of larval life in the laboratory after capture was 27 days for *C. dimidiata* and 15 for *C. silacea* but these figures related only to the earlier months of the fly season. Average length of pupal life was eight or nine days.

Tsetse Flies

During 1948–1951, some work was done on the distribution and habits of the species of *Glossina* in the Western Region of Nigeria in collaboration with the West African Institute for Trypanosomiasis Research.

Observations were made upon the resting habits of three species, *G. medicorum* Aust., *G. fusca* (Walk.) and *G. longipalpis* Wied. at Olokemeji Forest Reserve in late October 1949.

G. medicorum was not attracted to fly-boys with black and hessian screens, nor to a catcher with a pig. Searching for *G. medicorum* however, produced some 37 specimens on three days. In four days, only one specimen attacked humans, giving a painful bite below the knee.

The vegetation consisted of natural high forest closely underplanted with *Albizzia* sp. and *Bauhinia* sp. some of which attained a height of 20 to 30 feet. The bulk of the flies were found resting on saplings of *Albizzia*, usually about one inch in diameter.

With one exception flies were found resting head downwards on the shaded side of the trunk, the tips of the wings and abdomen resting on the bark and the anterior part of the body away from it. They were observed to rest between 1½ to 8 feet from the ground.

The use of screens and a bait pig failed to attract any *G. fusca* in the extensive natural high forest on either side of the main road. Tree trunks in the high forest were searched without success, but *G. fusca* was found on saplings in a teak (*Tectona grandis*) plantation, four specimens being taken by three collectors in an hour. All were resting head downwards at heights of from five feet to nine feet.

As with the previous two species, *G. longipalpis* was not attracted in a small clearing to a bait pig. Screens seemed to attract the flies but they usually settled within a foot or two on adjacent herbage. Twenty-five specimens were taken, only two of which were attracted to man.

The above is a summary of the paper by Nash & Davey (1951).

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The senior staff of the section has been as follows :—

A. Pickles, Senior Entomologist, April 1948–April 1950.
J. T. Davey, Entomologist, 1948–October 1951.
J. L. Gregory, Entomologist, March 1950–Present.
J. R. G. Sutherland, Senior Entomologist, February 1951–December 1953.

J. T. Davey was seconded to C.I.P.P.A.S. to study the solitary phase of the African Migratory Locust in October 1951. A separate report on this work, by J. M. Waterston, follows.

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STUDIES OF THE ECOLOGY AND SEASONAL MOVEMENTS OF THE SOLITARY PHASE OF THE AFRICAN MIGRATORY LOCUST (*LOCUSTA MIGRATORIA MIGRATORIOIDES*).

By J. M. Waterston

Since 1951, an entomologist of the Department of Agriculture, Mr. J. T. Davey, has been lent to the International Committee for the control of the Migratory Locust. This officer has studied in particular the seasonal movements of locusts from the known outbreak areas on the flood plains of the River Niger in the French Soudan, to the semi-arid areas west of these flood plains.

At first, movements were inferred from the changing densities of populations but, owing to the difficulty of assessing accurately the numbers of locusts in a given area, it was decided that only by marking and recapturing locusts could a formal proof of these movements be obtained. Thus a method was devised of marking individual locusts in large numbers by use of a hand sprayer and a dye solution. The method was first used on a large scale in the autumn of 1953. More than 50,000 locusts were marked in the semi-arid regions (known locally as the Farimaké), and later in the same year two of these locusts were recaptured on the flood plains. In the following months two more locusts were similarly recaptured and thus a formal proof was obtained that individual locusts (and possibly the whole population) produced in the Farimaké during the rainy season later migrate to the flood plains of the River Niger.

Of the movement out of the flood plains towards the Farimaké there is as yet no proof but such evidence as is available from changing densities suggests that such a movement takes place between June and August. The evidence is consistent in all the years from 1951 to 1953 and so it seems that these are in fact normal seasonal movements. It appears that the majority of locusts leave the flood plains at the beginning of the rainy season. Many arrive in the Farimaké where they breed and in the autumn, as the dry season approaches, their progeny return to the flood plains. Somewhat similar seasonal movements of swarms of the same species of locust have already been recorded by earlier workers.

Movements may be related to wind strength and direction, and there is some evidence that such movements occur at night. In fact no spontaneous flights have been seen during the daytime. At night, locusts were often as active on disturbance as they were by day, and on several occasions they were taken at light.

It is now possible to distinguish between areas such as the Farimaké where breeding, followed by great increases in numbers, may occur, and the region known formerly as the ' Outbreak Area ' where both increase in population and phase transformation take place. The numbers of locusts in the Farimaké—depending on the success of the breeding—presumably determine the numbers which will later arrive on the flood plains and this may have a determining influence on the production of hopper bands there. There is no evidence that such bands are ever produced in the Farimaké and, despite the high densities which may occur there, it is not suggested that control measures should be extended to include these areas. At the same time it is necessary to keep them under constant supervision and this may enable the control service to forecast from the numbers of locusts present in the Farimaké the possibility of the later development of hopper bands on the flood plains.

NORTHERN IRELAND

ECONOMIC ENTOMOLOGY, 1948–1954

By R. Chamberlain

All activities concerned with economic entomology in Northern Ireland are centralised in the Agricultural Entomology Research Division of the Ministry of Agriculture. This Division is responsible not only for research, specialist advisory work and routine technical services but also for University teaching.

In research, emphasis is placed on the applied aspects of local agricultural problems rather than on purely academic or long-range enquiries. Much of the investigational work is accordingly in the form of field experiments devoted to evaluating for use under Northern Ireland conditions the more recently developed insecticides. In this connection, during the period under review, chief attention has been focused on chlorinated hydrocarbons (DDT, BHC, toxaphene, aldrin, dieldrin), organo-phosphorus compounds (parathion, schradan, TEPP), summer ovicides (DPS, PCPBS, CPCBS) and dinitro compounds (DNC, dinoseb—especially the so-called ' Concentrated Winter Washes ').

These insecticide tests have been concentrated mainly on pest-control problems on (*a*) fruit—particularly apples, strawberries and blackcurrants, (*b*) vegetables—especially brassicas and carrots, (*c*) field crops—chiefly oats, potatoes, flax and root crops, and (*d*) glasshouse crops—principally tomatoes, lettuce and chrysanthemums. To a lesser extent, practical studies have also been undertaken relating to insect control in other crops including forest nursery stocks and plantation trees. In many of these fields the new insecticides have provided a marked advance over previous insect-control measures which they are rapidly superseding. Noteworthy among the control treatments which have proved highly successful experimentally, and which are now being generally adopted, are: DDT for Apple Capsids; BHC for Apple Aphids, Woolly Aphid and Apple Sawfly; summer ovicides for Fruit Tree Red Spider; seed treatment with BHC for flea beetles and Carrot Fly; dipping brassica transplants with toxaphene for Cabbage Root Fly; soil treatment with aldrin for wireworms.

Legislation designed to prevent the entry of foreign pests and to restrict the spread of indigenous pests includes the Importation of Plants (Northern Ireland) Order 1947, the Colorado Beetle (Northern Ireland) Order 1947 and the Bee Pest Prevention (Northern Ireland) Act 1945. The successful implementing of these legislative measures is largely dependent on a number of technical services which involve examination of imported commodities and ship inspections, the treatment or quarantining of certain introduced plant propagation material, field inspections of growing crops and apiaries and laboratory examinations of insect specimens and plant- and soil-samples.

During the period under review, 5 adult Colorado Beetles have been discovered in produce imported from Europe but no breeding colonies have as yet been found on potatoes in this country. Chrysanthemum Midge, which is not known to exist in Northern Ireland, was intercepted in 1948 in a small number of rooted cuttings imported from England. Codling Moth was recorded for the first time in Northern Ireland in 1952; the origin of the two small outbreaks, each confined to a few apple trees, has been traced to importations of overwintering larvae carried in used apple boxes from the south of England. The first discovery of Blackcurrant Leaf Midge in Northern Ireland was also made in 1952 and a subsequent survey has established that it is present in at least 18 plantations; the available evidence suggests that its introduction into the country is of fairly recent date and that the pest was almost certainly brought in with young blackcurrant bushes from Great Britain. Nosema disease of bees was first recorded in Northern Ireland in a single apiary in 1948 and subsequently in one apiary in 1952 and in three apiaries in 1953; all these infections were traceable to separate importations of queens and nuclei from England and all have been successfully eradicated.

A continuing important activity of the Division is concerned with a comprehensive survey initiated in 1944 to trace the incidence of the Potato Root Eelworm in Northern Ireland. The results to date present a very favourable prospect, particularly when compared with the position as reported in many other potato-growing countries; the foci of infection so far discovered are very limited in number and localised in distribution.

Under the Potato Root Eelworm (Northern Ireland) Order 1945, the eelworm is a notifiable pest and in cases where its presence is confirmed the Ministry of Agriculture prohibits the growing of potatoes or tomatoes on the infected land, the removal of soil from infected land, and the removal of vegetables, weeds, or plants to the roots of which any soil adheres. In 1951, with a view to minimising still further the possible spread of the eelworm, a new order—the Potatoes (Frequency of Planting) (Northern Ireland) Order—was introduced. The general purport of this order is that the four small areas where field infections have been discovered are scheduled, and within these areas the growing of potatoes in ' clean ' land is permitted not more frequently than twice in any period of eight years.

The volume of soil-sampling work in connection with the Potato Root Eelworm survey and certification schemes has been maintained at a steady level over a period of ten years; some 15,000 sites (fields, gardens, glasshouses, etc.) in different parts of the province have been sampled annually and the conclusions reached provide satisfactory evidence of the continued freedom from field infections in the main seed-potato producing districts. The laboratory findings have also evinced that the few cases of infection which have been confirmed are in the incipient stages and are largely confined to gardens or are located for the most part in the small areas scheduled under the Potatoes (Frequency of Planting) Order.

The most recent development in the research programme on Potato Root Eelworm control has been the commencement of practical studies on breeding resistant varieties of potatoes. Using certain lines of *Solanum andigenum* supplied by the Plant Breeding Institute, Cambridge, the local investigations are being undertaken in cooperation with a Northern Ireland Potato breeder.

NORTHERN RHODESIA

REVIEW OF WORK ON TSETSE FLY, 1948–1953

Department of Game and Tsetse Control, Northern Rhodesia

In the territory of Northern Rhodesia over half of the total area is either infested or influenced by tsetse fly. The predominant species is *Glossina morsitans* which is ubiquitous. *G. pallidipes* has also a widespread distribution in those areas which are ecologically suitable to it. The only other species found are *G. palpalis* and *G. brevipalpis*: of these, the former is confined to Lakes Tanganyika and Mweru and the Luapula river, whilst the latter is to be found only in scattered localities in the Northern and Eastern Provinces. From this it can be seen that most problems arising are concerned with *G. morsitans* or mixed *G. morsitans–G. pallidipes* infestations.

Prior to 1948, the existing map of tsetse distribution throughout the territory was compiled from reports received from many different sources and in some cases their veracity or interpretation was suspect. It was therefore decided to conduct a territory-wide survey with the following terms of reference:

(1) To map the existing *G. morsitans* belts with particular attention to seasonal fluctuation;

(2) to map the occurrence of any other species of tsetse fly;

(3) to correlate fly distribution with existing ecological conditions including vegetational types, animal habitats and movements, and the habits of the indigenous population;

(4) to analyse the above data with a view to economy in future anti-tsetse operations, with special reference to the use of discriminative clearing;

(5) to record any other information appearing to be relevant to the ecology and control of tsetses.

As the time allotted for the survey was comparatively short, it was intended that the basic information obtained would be elaborated in detail by the permanent staff of the department as the necessity arose.

One outstanding fact which has appeared from this survey is that a large number of cases of bovine trypanosomiasis occur from time to time outside the limits of the fly-belts, as the result of mechanical infection by biting flies other than tsetse, after an initial infection has been caused either by fly carried on travellers or by cattle straying into known fly-belts. The prevention of these sporadic outbreaks of trypanosomiasis is a problem of some concern to members of both the Game and Tsetse Control and Veterinary Departments, for any regulations imposed with the object of preventing such outbreaks must obviously be framed to allow normal trade and traffic to continue with as little hindrance as possible.

Since 1948, a variety of methods have been applied in the control of tsetse, some of them a continuation of operations instituted prior to that date and others a direct outcome of information acquired in the afore-mentioned survey. In all cases the economics of any project were of prime importance; thus, except where conditions necessitated immediate action to prevent deterioration of an existing position, the following principles have been emphasised:

(*a*) land is to be cleared only as and when it is required for immediate use;
(*b*) either directed settlement is to be incorporated in the eradication methods, or any success achieved is to be consolidated as quickly as possible by settlement at the maximum density consistent with the agricultural potential of the cleared land.

Under conditions in Northern Rhodesia it is essential that tsetse eradication should proceed hand in hand with, and not outrun, the needs of general development of the land. Many of the areas under ' fly ' are remote and inaccessible, and large-scale operations are thus rendered the more difficult and costly. Frequently it is essential that a scattered native population be first concentrated into a selected area in order to provide some economic basis for an attempt at reclamation and to mitigate as far as possible the difficulties attendant on trying to maintain a fly-free pocket in the midst of a large fly-belt.

From the detailed account which follows it will be noted that, in many instances, more than one method of control has been applied in a particular area: this has been done after due consideration of the conditions existing in these areas with the object of reducing costs and expediting the final result.

Discriminative Clearing

(*a*) *Abercorn*

Operations were begun in this area in 1936 under the auspices of the East African Tsetse and Trypanosomiasis Research and Reclamation Organisation, and continued until 1949 when they were handed over to the Northern Rhodesia Game and Tsetse Control Department. In general they consisted of the clearing of drainage lines in *Brachystegia–Isoberlinia* woodland, and, to date, eradication remains complete. A continual check has been maintained in this area and the possibility of reinfestation from adjacent fly-belts has been deterred by a series of de-flying pickets. The method has been carried a stage further at Malombe, to the south-west of the original operation; here the clearing was accomplished at no cost by the siting of ' chitemene ' (lopped tree) cultivations of the indigenous Africans in the fly concentration areas which were found by surveys conducted by trained African staff. This method has been successful but is strictly local in its application. An attempt to duplicate it at Munkonge on the Kasama–Luwingu road has not produced equivalent results, probably due to the smallness of the ' chitemene ' clearings compared with the extent of the concentration areas. A further attempt is now being made to assist eradication here by clearing, with paid labour, between the ' chitemene ' sites.

(*b*) *Chingola*

The advent of civilisation and its attendant increased human activity in and around the Copperbelt of Northern Rhodesia has caused a large-scale recession of fly from its former habitat. A pocket of some 200 square miles was left just west of the Chingola township: this constituted a menace to the cattle of existing farms and inhibited any extension of farming. The pocket is now being attacked by discriminative clearing which to date has consisted of the clearing of ' dambo ' edges and drainage lines in *Brachystegia–Isoberlinia* woodland. The operation has not been in force long enough for any comment to be made on the results. A belt of commercial wood coupes has also been sited between the fly limits and the settled land to assist in further isolation of the pocket.

(*c*) *Muchila* (*Namwala District*)

Over a period of several years, encroachment of *G. morsitans* had taken place in the south of Namwala district, causing villages and cattle to retreat before its advance. It was decided for a variety of reasons to attack the fly by discriminative clearing in the outermost concentration areas rather than by barrier clearing. One concentration on the Shikaleta river, some 50 square miles in extent, is now being cleared. From information gained by regular fly-rounds it has been found necessary to clear ' dambo ' edges, drainage lines and ' mopani '–*Brachystegia* and ' chipya '–*Brachystegia* interzones. The indications are that the advance has been halted and there is a reduction in the number of fly caught. Clearing is being continued both laterally and into the fly-belt.

Discriminative Clearing with Resettlement

Since 1949, human trypanosomiasis has been increasing in an area with a mixed *G. morsitans–G. pallidipes* infestation across the Mumbwa–Namwala road. This fly concentration also menaces an adjacent area scheduled for intensive agricultural development. After preliminary investigation it was decided to concentrate the population of the three African chiefs involved into the smallest possible area inside the fly-free flank, and to attack the fly within this area by discriminative clearing. A start was made on moving the population in 1953 and discriminative clearing is being carried out on 'dambo' edges and in ant-hill thicket. An intensive medical survey has been undertaken and all infected persons discovered are treated. There is also a comprehensive programme for the provision of wells and weirs to aid in close development of the land. A small experiment in the use of arboricides has been incorporated in the tsetse control work, but the results will not be available for some time.

Discriminative Clearing augmenting Barrier Clearing

Kalomo

From 1930 onward, *G. morsitans* encroached from the north onto the farm lands around Kalomo. The native population withdrew before the advance and the fly eventually appeared on the edge of some European farms. A partial barrier clearing was created as a temporary measure to contain any further advance, and in 1950, fly concentrations behind the barrier were attacked by the clearing of 'dambo' edges and drainage lines in *Brachystegia–Isoberlinia* woodland. The encroachment has been halted and land is now being reclaimed from the fly. Unfortunately the land outside the boundaries of the European farms is almost uninhabited and it has been impossible up to the present to resettle any African population to consolidate gains made.

Game Elimination with a Game Fence

(*a*) *Kafue North Bank Fence*

On the north bank of the Kafue river in Namwala district, the cattle which normally graze on the riverine flood-plains of the Kafue were forced annually by the rising waters into the fringing tsetse bush, with consequent losses from bovine trypanosomiasis. A game fence 57 miles long was constructed to enclose an area of bush sufficient to provide adequate flood-time grazing, also to halt the annual migration of large numbers of game animals from the bush to the plains in the dry season. In 1950 the fence was completed except for a 14-mile gap and a game drive was then held, assisted by the Northern Rhodesian Regiment, to shepherd any game living in the bush inside the fence through the gap and out beyond the fence line. The gap was then closed and any game remaining in the bush inside the fence was destroyed. Breaks through by game from outside the fence have been remarkably few, and the annual migration has been stopped. Fly (*G. morsitans* only) has diminished considerably inside the fence area, and is now confined to two small residual pockets which are gradually being eliminated. It had been intended to incorporate a 1,000-yard barrier clearing along the fence line to prevent influx of fly from the untouched fly bush beyond, but the cost proved prohibitive, and an attempt is now being made to achieve isolation by augmenting the population inside the fence, and by siting the cultivations of this settlement in the most likely lines of ingress.

A small experiment to test the efficiency of arboricides in aiding bush clearing on behalf of the settlement was carried out at the end of 1953: definite results are not yet available.

(*b*) *Msoro*

A short fence, some 16 miles, was constructed to the north of Msoro Mission in the Eastern Province to assist in the eradication of a *G. morsitans* infestation. Human trypanosomiasis was rife in this area, and this has been considerably reduced. Elephant are proving very troublesome and a great deal of difficulty is being encountered in keeping the fence intact. It is interesting to note that on the Kafue, where elephant are comparatively rare, the fence has proved efficient against almost all other game including large numbers of buffalo, but that, at Msoro, elephant are responsible for most of the breaks through and damage to the fence.

Game Elimination without the Aid of a Fence

(*a*) *Feira*

This campaign was instituted against human trypanosomiasis in the Lower Luangwa Valley south of the Great East Road. Game was eliminated from between the escarpment and the Luangwa river, and, aided by some discriminative clearing of hard-pans and thicket, a mixed *G. morsitans* and *G. pallidipes* infestation has been eradicated. In the Zambesi Valley a collateral attempt to maintain a fly-free pocket by game elimination and a barrier clearing around the Chakwenga–Zambezi confluence proved unsuccessful. The population was accordingly moved from this area and resettled on the Luangwa front. With this consolidation of population and control work, sleeping sickness has been reduced to negligible proportions, and almost all of the few cases which have occurred recently have been proved contracted outside the cleared area.

(*b*) *Fort Jameson*

G. morsitans had by the early 1940s encroached to the outskirsts of Fort Jameson township. Game elimination, aided by discriminative clearing of hard-pans, was carried out within a prescribed perimeter and the fly has been pushed back up to 30 miles from the town. Operations are now being directed towards the elimination of a few residual salients and the maintenance of the fly boundary. To reinforce the gains made, native settlement is being fostered in selected areas, dams and wells being provided to this end.

Game Elimination with Discriminative Clearing

Broken Hill

An infestation of *G. morsitans* extending up to Broken Hill township was attacked by shooting out game along a 20-mile front. After some initial success it was found that the fly was emanating from a focus around the Mulungushi Dam some 25 miles east of Broken Hill. Further game elimination failed to attain total eradication, so this measure was augmented by the clearing of ‘dambo’ edges and drainage lines within the fly concentration area. Eventually these concentration areas were reduced to very small dimensions, and it was found that the ‘chipya’–*Brachystegia* ecotones were harbouring most of the residual fly. After further discriminative clearing, and because the pocket of fly was completely isolated, the opportunity was taken to attempt final eradication by means of insecticide, both residual and aerosol, applied from the ground by a T.I.F.A. Though some 90% reduction of fly was achieved the fly began to recover slowly at a later date. It is intended to continue application in 1954. The position has meanwhile been stabilised by the siting of intensive native cultivation and of the Broken Hill Mine wood coupes between the town and the remaining fly pocket.

Lake Shore Clearing

Sleeping sickness with *G. palpalis* as the vector was present on Lake Tanganyika in the vicinity of Mpulungu. The fly has been eradicated from this vicinity by clearing a belt 100 feet in width along the lake shore. It was found necessary to remove most of the reeds and smaller growth, as well as the trees, to achieve total eradication.

PAKISTAN

REVIEW OF THE WORK IN ECONOMIC ENTOMOLOGY, 1948–1953

Ministry of Food and Agriculture, Department of Plant Protection, Karachi

Due to insect pests and diseases the annual losses to the agricultural crops in Pakistan are approximately 10–15%. One of the most practical methods of increasing food production is to eliminate these losses by adopting plant protection measures. In order to achieve this object the Department of Plant Protection in the Ministry of Food and Agriculture, Government of Pakistan, was established since the birth of the State in August, 1947. During the last six years this Department has considerably expanded and its activities are mainly concentrated on problems of All-Pakistan and international importance. The Department at present consists of five Divisions—Locust, Plant Protection, Quarantine, Food Storage and Plant Pathology. The work done by the first four during the years 1948–53 is summarized as follows:—

Locust Division

The Desert Locust (*Schistocerca gregaria* Forsk.) presents a major problem for the successful cultivation of agricultural crops in Pakistan which occupies a very vulnerable position with regard to this insect. Unlike many other countries affected by this plague, Pakistan has both summer and spring breeding areas. It is invaded by locust swarms from the west after the end of spring breeding in Arabia, Iran, Afghanistan, etc., usually from the middle of May onwards and by swarms from the east at the end of summer breeding in India, usually from about the middle of October.

The problem of locust control has entirely different and peculiar features from that of other crop pests owing to extensive swarm migrations of locusts and their incipient breeding in the uninhabited and unapproachable desert areas. By virtue of the rapid migrations of this pest over thousands of miles the locust problem is not only inter-provincial but international, and co-ordinated efforts in the whole desert region extending over a number of countries are essential to destroy breedings before swarm formation. Weakness in any single link of the whole chain can undo the good work done in other countries.

The Department has thus built up an up-to-date locust organization equipped with trained staff, motor transport, control equipment and aerial unit. This organization co-ordinates locust control work within Pakistan and with the adjoining countries. The staff of this organization surveys the desert areas, records fluctuations of locust population, collects the information from all desert outposts, provincial Governments and neighbouring countries and issues periodical bulletins for the information of all concerned. They also organize and supervise the control operations, particularly in the desert areas. In the case of heavy breedings, a substantial part of the staff engaged in the other Divisions of the Department is also sent out for locust control. In the control operations the technical staff is helped by the local Revenue authorities. During the active season the Revenue authorities increase the number of their officers and depute them wholetime for locust work.

Realizing the importance of attacking the pest in its outbreak centres lying in the desert areas, Pakistan Government enforced, right from 1947, a co-ordinated control scheme according to which all the provinces and states in Pakistan contribute to a central pool in proportion to their cultivated areas liable to locust damage. This scheme, originally planned on a small scale, was greatly expanded in July 1951, resulting in the formation of a high-powered Locust Control Committee and the raising of over half a million pounds sterling for organizing control work both in the desert and cultivated areas of West Pakistan.

Pakistan has been passing through swarming locust cycle since 1949 and vigilant and efficient anti-locust campaigns have been carried out by our anti-locust organization. The following account will show the extent of infestations that occurred in Pakistan since the beginning of the cycle and the successful control operations carried out:—

Year	Area infested
1949	8,000 sq. miles.
1950	13,000 sq. miles.
1951	136,000 sq. miles.
1952	26,000 sq. miles.
1953	7,000 sq. miles.

The results of the intensified efforts were that except once when our crops were affected by the invading swarms, there had been practically no loss to our agriculture by the breedings which have taken place in Pakistan.

The main methods of control adopted in Pakistan are spreading BHC and aldrin baits, spraying and dusting both with ground machinery and with aeroplanes and driving the hoppers into trenches and burying them therein. Spraying of the insecticide aldrin at the rate of 1·72 ounces per acre by fixed-wing light aeroplanes gave excellent results and this method is now carried out on a large scale against hoppers. In the United States of America and other countries aldrin was dissolved in diesel oil as it is insoluble in water, but Pakistan has made a valuable contribution by emulsifying aldrin successfully in water, thus not only reducing the cost on diesel oil but also solving the difficult problem of transport of large quantities of oil to the roadless deserts. On noting this discovery the manufacturers have now produced water emulsifiable aldrin which is being used everywhere for locust and grasshopper control.

Aerial spraying of aldrin against hoppers was carried out for the first time in 1951 and this proved particularly effective for meeting serious situations. This can be judged from one typical case where a cotton belt of several thousand acres adjoining the Tharparkar desert (Sind) was threatened with destruction by hoppers in September, 1952. The hopper bands marched into cotton fields after forcing their way through the ground control organization. Aerial unit was switched on to the cotton belt and three planes making 9–10 trips daily sprayed about 5,000 acres of cotton in 3 days and before the hoppers could do any damage the situation was brought under control. Another instance where aerial spraying against hoppers proved very successful was the clearing of hopper menace along the main railway track near Karachi. Thick hopper bands after being crushed under the wheels of the engine made the track and the wheels so slippery that the engine was unable to pull the train. The affected area of about 60 miles of railway track and the infested strips on both sides were cleared by aerial spray within three days. Another interesting aspect was the successful spraying of freshly formed swarmlets and pairing swarms in two cases. Three planes cleared an area of 20 sq. miles of freshly formed swarmlets in a single day.

Aldrin has also been used for the first time on a large scale in rice husk baiting. Five ounces (100 c.c.) of 60% aldrin mixed in 100 lb. of rice husk were generally employed but it was later found that even $2\frac{1}{2}$ ounces in 100 lb. of carrier or one part of pure aldrin to one thousand parts of rice husk gave very satisfactory results against all stages of hoppers and adults. Aldrin bait is now used on a large scale and is gradually replacing BHC baits.

Until recently, practically all locust control campaigns had been directed towards the destruction of the hopper stage. In cultivated areas flying swarms, particularly when fresh, may do incalculable damage to crops. Realizing the importance of the control of swarms for successful locust campaigns, attempts have been made to spray aldrin on locust swarms under different conditions—on flying as well as settled swarms, on mature and freshly formed swarms, on pairing and feeding swarms, etc. The task of initial location and spraying of these swarms turned out to be extremely difficult, while the tracking of dead individuals, after spraying, many miles away from the place of operations seemed well nigh impossible. Nevertheless, some useful data have been collected which may lead to more successful results in the future. This experience has indicated some of the conditions under which aerial spraying of swarms may be practicable. These are:—

(1) Freshly formed swarms (not more than 3 to 5 weeks old) which are rather sensitive and weak fliers, can be easily sprayed and killed by aldrin spray.

(2) Mature swarms near egg laying, which do not fly long distances, and copulating swarms can also be effectively sprayed, but the mortality is not complete with 4 oz. to a gallon dose of aldrin.

(3) Swarms benumbed by cold nights can also be sprayed effectively early in the morning.

Apart from control experiments, research on the biology of the Desert Locust, food preferences of the hoppers, behaviour of hoppers and adults, insecticidal trials, parasites and predators, etc., are in progress.

PLANT PROTECTION DIVISION

The important activities of the Division of Plant Protection are: Studies of insect pests of inter-provincial importance, establishment of an insect Museum, survey and studies of insect fauna of Karachi, introduction of plant protection schemes in various units of Pakistan, coordination of plant protection measures in different parts of the country and testing and evaluating new insecticides and equipment.

Insect Museum

Before partition the only Insect Museum of agricultural importance in the sub-continent was at New Delhi and with the establishment of Pakistan we received a very small number of identified specimens from India, thus we had to organize our Museum from the very beginning. We are now establishing the Museum on proper lines and at present have over 5,000 identified specimens to which more are being added. It is hoped that in due course our Museum will be rich in collection and will be used for reference by entomological workers in Pakistan. Regular surveys for the collection of insect fauna of Karachi and Malir areas are under progress and a number of new species have been collected.

Crop Pests

The Black-headed Cricket

Acheta domesticus L. is a serious pest of ripe wheat and oilseeds, both in the field and thrashing floors, and of germinating cotton and millet, in an area of about 2,000 sq. miles in the adjoining parts of Sind, Baluchistan and Kalat State of West Pakistan. For the last five years a co-ordinated scheme has been in progress and the following aspects have been particularly studied: biology of the cricket, including its life and seasonal history; feeding habits of the pest; amount of damage done and requirements of the insect during different seasons, including mode of feeding and food preferences; population studies of the insect and its distribution during different seasons and at different localities; and cheap and effective methods of control. The investigations have been finalized and the results obtained have led to control the pest effectively. As this pest gradually builds up its population from mid-January to the beginning of April, baiting or dusting with BHC or aldrin in the infested pockets and the raised boundaries of crop-fields which are the main places of pest-breeding can check the later outbreak of the crickets. BHC bait consisted of one part of gamma isomer to 1600 parts of rice husk while the ratio in case of aldrin bait was one part of insecticide to 1000 parts of the carrier. The rate of BHC dusting was 0·125 lb. gamma isomer per acre.

The baiting technique consisted in throwing handfuls of bait at intervals of 2–3 ft. on the boundaries of crop-fields. During the actual outbreak period, the same method of dusting and baiting employed around the threshing floors can kill the crickets. It is estimated that on an average 14,000 maunds of food grains are being saved annually by adopting these control measures.

Sugar-cane borer

In 1948–49, the culture of *Trichogramma minutum* Riley, bred on *Corcyra cephalonica* Stn. for the control of sugar-cane stem borers in certain parts of Sind was done and liberated in sugar-cane fields during 1950–51 and it has been recorded that parasitization of eggs of the borers was about 60–70 % in the fields, showing that the parasite could exercise a useful check on the pest in Sind.

Control of fruit pests

In the Kurram Agency of N.W.F.P., the Codling Moth (*Cydia pomonella* Linn.) damaged up to 80 % of apples, pears and quinces. In order to control this pest a scheme was put into operation in 1949 and four years of campaign has brought the pest under complete control. On an average about 75,000 fruit trees are treated annually with 0·25 lb. of DDT and 0·25 lb. of lead arsenate per tree. Apart from Codling Moth, other major pests found in the Agency, *viz.*, *Hyponomeuta padella* Linn., *Euproctis signata* Blan. etc., have also been controlled successfully and as a result thereof, the fruit industry which was on the verge of being ruined has been saved considerably.

In the N.W.F.P. an anti-fruit-pest scheme was started in 1949 and as a result of campaigns organized by spraying and dusting about 870,000 fruit trees every year, the fruit production of the province has been increased besides raising the quality of healthy and marketable fruit. As an example the fruit-fly (*Dacus* (*Strumeta*) *ferrugineus* Fabr.) which used to render the fine peaches of the province unfit for export has now been brought under control by spot spraying of sweetened stomach poisons (0·1 % DDT or BHC) and collection and burning of affected fruits. The fruit is now exported in large quantities to other provinces. As a result of increased production the fruit cess which was only about Rs. 300,000 in 1948–49 is now more than four times this figure. A similar scheme in Baluchistan is yet in its initial stages. Anti-crop-pest schemes have also been sanctioned for Sind and East Bengal Provinces.

Mango Hopper control

During 1953 a total of 10,041 trees of mango, *Citrus* and "jaman" (*Eugenia jambolana* Lam.) were sprayed against Mango Hopper (*Ideocerus* spp.) in Khairpur State. The dosages of gamma isomer of BHC and DDT, the two insecticides used, were 0·045 lb. and 0·15 lb. per tree respectively. The cost of insecticide comes to about Rs. –/8/– per tree. Encouraged by the good results achieved in the campaign organized during 1953, a general plant protection scheme for that State has been sanctioned for 1954 and control operations against Mango Hopper on a large scale have been started.

Emergency Food Committee Scheme

On account of food shortage in Pakistan, the Ministry of Food and Agriculture set up an Emergency Grow More Food Committee in 1953 which sanctioned short and long term grow more food schemes. With this Committee's funds a number of anti-crop-pest schemes have been introduced by this Department in various provinces, the most important ones being : Control of Rice Borer (*Schoenobius bipunctifer* Wlk.) in Punjab and Sind, control of Sugarcane Pyrilla (*Pyrilla* sp.) in N.W.F.P., control of Rice Fulgorid (*Sogata distincta* Dist.) in Sind, etc. Large quantities of insecticides and equipment were purchased early in 1953 under these schemes which were put into operation in collaboration with the local agricultural and Revenue Departments during the *rabi* season of 1953.

Rice Borer control

Under the Rice Borer scheme, a total of 7,741 acres of paddy fields as well as nurseries for sowing 86,760 acres were treated with BHC and DDT formulations, at the rate of 0·125 lb. of gamma isomer of BHC and 0·5 lb. DDT per acre. Due to control measures adopted, apart from producing healthy paddy nurseries, the crops were saved to a great extent in the treated areas. To cite an example, in Muzaffargarh district of Punjab the borer infestation in seriously affected areas came down from 50–90% to 10–15%.

Rice Fulgorid control

This pest was recorded for the first time in Sind doing damage to rice leaves and stem and subsequently killing the plants. In 1952 this pest inflicted a loss of about 60%. When the outbreak commenced in the autumn of 1953 an aerial spray unit was switched on and about 9,000 acres of severely affected fields were treated with aldrin and endrin sprays. The pest was thus brought under complete control.

The following dosages of different insecticides were found effective against this pest:—

Spraying with ground machinery	
Gamma isomer of BHC	0·12 lb. per acre
Endrin	0·01 lb. per acre
Malathon	0·0143 pint per acre
Aldrin	0·131 lb. per acre
Aerial spraying	
Endrin	0·1 lb. per acre
Malathon	0·143 pint per acre
Aldrin	0·162 lb. per acre

Sugarcane Pyrilla control

In the N.W.F.P. about 120,000 acres of sugar-cane are infested by *Pyrilla* and as a result of campaigns organized in the Province, 46,375 acres which were more severely infested were sprayed during 1953 with BHC, endrin and malathon with very good results. The per acre effective dosages for ground spraying of endrin and malathon worked out after extensive trials, were 0·1 lb. and 0·143 pints respectively as compared to 0·36 lb. of gamma isomer of BHC. This has reduced the cost of insecticide from Rs. 6/–/– to Rs. 1/12/– per acre. In aerial spraying 0·2 lb. of endrin or 0·286 pints of malathon per acre were found equally effective. Encouraged by these results there is now a heavy demand of insecticides and equipment and the local farmers have liberally and willingly contributed towards the purchase of the equipment for the next season of 1954.

Cottage Industries

Demonstrations for the rearing of silk worms and honey bees have also been conducted with a view that the people might take up these as cottage industries.

New and Cheaper Insecticides

During the field campaigns, trials to test the new insecticides coming on the market were also conducted to find out their efficiency and comparative cost. Of these, aldrin, malathon 50%, endrin 19·5%, dieldrin, Systox and Folidol were tested and minimum doses have been worked out in each case. This has enabled us to cut down the cost of insecticides in certain cases by at least 50%.

The use of endrin and malathon is now recommended for the control of *Pyrilla* pest at the following doses as compared to BHC:—

Quantity of Insecticide per Acre

	Insecticide	Aerial spray	Ground spray
1.	BHC 12%	—	3 lb.
2.	Endrin 19·5%	0·125 gallon	0·0625 gallon
3.	Malathon 50%	0·071 gallon	0·035 gallon

In addition to the effective control obtained by these insecticides there is a marked residual effect of endrin lasting for a period of 2–3 months, so that any reinfestation of the crop is eliminated.

Similarly in the control of Rice Fulgorid, the dose per acre is as follows:—

	Insecticide	Aerial spray	Ground spray
1.	BHC 12%	—	1 lb.
2.	Endrin 19·5% emulsifiable	0·0625 gallon	0·00625 gallon
3.	Malathon 50%	0·0355 gallon	0·0035 gallon

In the control of Black-headed Cricket, aldrin has replaced BHC. The dose of BHC was 0·0625 lb. of actual gamma isomer per 100 lb. of rice husk or one part of gamma isomer to 1,600 parts of rice husk. The minimum effective doses have now been worked out to be 2·5 to 5·0 oz. or 50 c.c. to 100 c.c. of aldrin 60% per 100 lb. of rice husk or one part of aldrin to 1,000 or 500 parts of rice husk.

Against Black citrus fly, a number of insecticides have been tried and it was found that malathon 50%, Folidol 47%, Systox 23% and endrin 19·5% emulsifiable were quite effective against this pest at the minimum doses of 2 cc., 1 fluid oz., 1·2 fluid oz. and 3 cc. per gallon of water respectively.

The same insecticides were tried in N.W.F.P. on fruit pests particularly scale insects and mealybugs and a minimum effective dose of 0·03% of Systox or Folidol for Aphids and 0·06% of the same insecticides for mealybugs have been worked out.

FOOD STORAGE DIVISION

The annual damage caused by stored-grain pests in Pakistan is estimated to be about 6 % or more than one million tons of grains. The food storage Division of the Department is engaged on the practical control of these pests—evolving better types of storage and looking after large quantities of grains imported from foreign countries, particularly large stocks of grains at Karachi where the warm and humid climate is most congenial to the breeding of stored-grain pests. As a result thereof, about 0·5 million tons of food grains have been fumigated to date—mostly by ethylene dichloride/carbon tetrachloride and partly by hydrocyanic acid gas, under improvised conditions using ordinary tarpaulins, in railway wagons and also in ships carrying food grains. Disinfection of empty godowns, storage plinth and mill warehouses covering about an area of one million square yards was also carried out with standard formulation of BHC and DDT preparations. Apart from this, examination of about 70 ships bringing wheat from U.S.A., Canada, Turkey, Australia, Burma, Russia and other countries was also carried out in order to check the incoming of exotic insect pests along with the imported grains.

Fumigation of wheat in ship-holds by ethylene dichloride/carbon tetrachloride which was hitherto considered by foreign experts as hazardous and ineffective on account of improper dispersion of the fumigants, was successfully carried out in two ships carrying wheat to Japan and the results obtained are highly satisfactory.

A survey of the insect pests of the stored grains has been completed and it has been found that apart from the common stored-grain pests hitherto recorded in the Indo-Pakistan sub-continent, the following seven other insects not hitherto recorded and associated with stored grains in Pakistan have been collected from the godowns at Karachi.

Thorictodes heydeni Reitter (Tenebrionidae), *Saprinus* sp. (Histeridae), *Opatroides punctulatus* Boul. (Tenebrionidae), *Scleron sulcatum* Bandi (Tenebrionidae), *Peregrinator biannulipes* Montr. (Reduviidae), *Amphibolus venator* Klug. (Reduviidae), *Xylocoris flavipes* Reuter (Anthocoridae).

The biology of these insects together with those of others recorded are under study.

The fumigation of milled products like " *atta* " (flour) or " *maida* " (fine flour) is very difficult on account of high absorption of the fumigants by the products, the compactness of the commodity and their property of " fat solubility ". Experiments planned to determine the effect of ethylene dichloride/carbon tetrachloride on these milled products with a dose of 100 lb./1,000 maunds under ordinary temperatures have given highly satisfactory results. These are now recommended on a large scale.

On account of its delicate nature and high water absorption capacity " *maida* " is difficult to store for a long period under the humid Karachi climate. Sometimes large quantities of this commodity are received from abroad. In order to overcome this difficulty, and as an experiment, " *maida* " was stored successfully and without any deterioration for several months by proper selection of a suitable godown, disinfection of stores with BHC and DDT formulations and strict adherence to store-hygiene.

The control of insect pests associated with the pulses is one of the most important problems in Pakistan. Four species, *viz.*, *Bruchus chinensis* Linn., *Bruchus analis* Fabr., *Bruchus phaseoli* Gyll. and *Bruchus* sp. have so far been recorded in Karachi associated with gram and other pulses. The study of comparative damage done by these pests has shown that the " whole " *dals* are infested more heavily than the " split" ones.

The standard dosage of the fumigants depends largely upon the rate of absorption shown by different grains. In view of this, experiments have been planned and rates of application of the fumigants for stored grains in relation to the absorptive capacities of different grains are being determined.

Trogoderma khapra Arr. (*granarium* Everts) is more resistant than other stored-grain pests to the various insecticides and experiments are being conducted to test the standard insecticides and fumigants against this insect.

Rice is an important food commodity of Pakistan and studies on the comparative damage done to the different varieties of rice by different stored pests have been initiated and completed.

It has been estimated that due to inadequate storage of grains by the farmers the losses are about 5–10%. Three types of suitable bins for the safe storage of the produce have been evolved as follows:—

1. Reinforced cement concrete of 10 and 15 maunds capacity.
2. Steel bins of 50, 150 and 800 maunds capacity.
3. Wooden hexagonal bins of 135 maunds capacity.

Of these the steel bins have proved to be the best and are recommended to the farmers.

Due to the unique climate of Karachi which is hot and humid and the city assuming importance on account of heavy import and export of food grains, a regular survey of stored-grain pests is being carried out and the biology and seasonal activities of these are constantly under study with a view to predicting outbreaks and planning their control at the proper time.

QUARANTINE DIVISION

As an agricultural country, Pakistan is fully conscious of the importance of protecting its agriculture from the introduction of foreign pests. Unfortunately before the creation of Pakistan very little care has been taken to prevent the entry of crop pests from Afghanistan, Iran, or through western land borders. Unrestricted imports of fruits from neighbouring countries enabled the entry of serious pests like Codling Moth (*Cydia pomonella* Linn.), *Hyponomeuta padella* Linn., *Spilonota ocellana* Schiff., *Eurygaster maura* Linn., San José Scale, etc., hitherto unknown in this sub-continent, and their establishment and spread in N.W.F.P., Baluchistan and the adjoining Agency areas. Pakistan also holds a strategic position between the eastern countries possessing an oriental fauna and the western countries having a distinct palaearctic fauna. Thus Pakistan is the gateway for the migration of palaearctic pests to all countries in the Far East and in its own interest and in the interest of all Far East countries, Pakistan has set up Quarantine restrictions against the entry of exotic insect pests and diseases of economic crops, vegetables and fruit plants.

The Plant Quarantine Service in Pakistan has been organized since 1948 and four inspection centres have been established with headquarters at Karachi.

The Plant Quarantine Station at Karachi deals with the imports by air and sea. Two stations established at Jamrud (N.W.F.P.) and Chaman in Baluchistan deal with the inspection of plant material imported through land routes. These stations are mainly to guard against the likely infiltration of the palaearctic species in areas adjoining the border between the Oriental and Palaearctic regions. The fourth station at Chittagong serves East Pakistan.

Inspection of Imports by Air and Sea

During the period from 1950 to 1953, a variety of infested plant materials was intercepted at the Karachi Airport which included both the authorized and unauthorized imports. The intercepted plant material together with the insects and diseases recorded on them are given in Tables I and II respectively. The material intercepted consists of different kinds of cut flowers, flower bulbs, plant cuttings and flower seeds, *Citrus* fruits, apples, pomegranates, mangoes, pears, peaches, plums, grape-vines, bananas, guavas, pineapples, chiku, endive, vegetables, cabbage, lettuce, cucumber, coffee, melons, khirni, lichees, tomatoes, dates, sugar-cane cuttings, olive plants, potatoes, strawberries, cherries, etc.

TABLE I

Details of intercepted material

Year	Total no. of consignments intercepted	Consignments released	Consignments destroyed
1950	200	25	175
1951	741	481	260
1952	766	576	190
1953	653	523	130

TABLE II

Details of pests recorded

Plant host	Pest	Country of origin
Cut flowers	Thrips	Holland, Rome, Singapore and Cairo
Pineapples	Mealybugs	Colombo, Nairobi
Maltas (*Citrus*)	Mediterranean fruit-fly (*Ceratitis capitata* Wied.)	Cairo (Mediterranean countries)
Dates	*Ephestia* sp. *Oryzaephilus* sp.	Arabian countries (Baghdad, Basra)
Lichees	Mealybugs	Bangkok
Figs	Scales	India
Pomegranates	Lepidopterous larvae	Iran, Afghanistan and Arabian countries
Apples	Codling Moth	Iran, Afghanistan

The maritime imports included tobacco from India and United States, cotton from United States, ornamental plants from Holland, coffee from India and Africa, potato and other plants and plant products most of which were meant for use at the Government Experiment Stations. The imports by sea were practically free from insects pests and diseases.

Land Route Inspection

A variety of fresh and dried fruits, mainly pomegranates, apples, pears, quinces, apricots, grapes, raisins, almonds, etc., etc., were imported in large quantities from Afghanistan and were found infested with insect pests and diseases. Some of the important pests recorded from different fruits are given below:—

Codling Moth, on apples, pears and quinces; *Euzophera* sp., on pomegranates; scales, on apples, pears and apricots; *Silvanus* spp., on raisins and apricots; *Ephestia* sp., on dried apricots and other dried fruits; powdery mildew, on grapes. A doubtful record of the wart disease of potato which was hitherto unknown from the sub-continent was made on foreign varieties of potatoes in East Pakistan. The survey of this disease of potatoes has been taken up to find out if this disease is present anywhere in East Pakistan or not.

Plant Materials Exported from Pakistan

Examination and treatment of the plants and plant products meant for export to foreign countries is systematically carried out. Necessary phyto-sanitary certificates were granted so as to meet the plant quarantine requirements of the importing countries. These exports included dried fruits, cotton, cotton seed, jute, ornamental plants, fruit seedlings, etc.

SCOTLAND

REVIEW OF ENTOMOLOGICAL WORK RELATING MAINLY TO AGRICULTURE AND FOOD STORAGE, 1948–1954

ORGANIZATION

In Scotland, the Agricultural Advisory Service is based on the three Agricultural Colleges at Edinburgh, Glasgow and Aberdeen and the country is zoned accordingly. Attached to each College is a small staff of Advisory Entomologists, who collaborate with the Regional and County Agricultural Advisers in providing the farmers, nurserymen and gardeners with advice on the identification, biology and control of pests destructive to crops and livestock. To this end, the Advisory Entomologists also co-operate in conducting field experiments designed to test or demonstrate the value of new or prescribed control measures and, where local knowledge is inadequate, carry out investigations on the bionomics of particular pests for the purpose of obtaining more effective means of control.

Supporting this structure are the resources of the Agricultural Research Institutes. Of these, particular mention should be made of the Scottish Horticultural Research Institute, established at Invergowrie, Dundee in 1951, where entomological research mainly on the transmission of the virus diseases of raspberries, strawberries and potatoes is in progress.

In addition, the Department of Agriculture maintains a Section of Entomology and Helminthology at its Seed Testing, Plant Registration and Plant Pathology Station at East Craigs, Corstorphine, Edinburgh and a Food Infestation Control Section with headquarters in Glasgow.

While the former (established in 1949) is concerned with the entomological aspects of crop protection and certification, the latter (transferred from the Ministry of Food in 1947) deals with the entomological problems of food storage.

Liaison between the various Entomologists concerned with the incidence and control of crop pests is maintained by a Departmental Conference, first convened in 1952 and held twice or thrice annually since then, to which the senior University Lecturers in Agricultural Entomology are also invited.

INCIDENCE OF THE MORE IMPORTANT INSECT PESTS OF CROPS

While wireworms (*Agriotes* and *Athous* spp.), leatherjackets (*Tipula* spp.) and cutworms (*Agrotis* spp.) were frequently abundant and caused considerable injury to cereals, pasture and various field and garden crops, more specialized pests of annual importance included flea beetles of several kinds, Cabbage and Turnip Root Flies (*Erioischia brassicae* Bouché and *E. floralis* Fall.), bean weevils (*Sitona* spp.) and Carrot Fly (*Psila rosae* F.).

In widespread outbreaks, Winter Moth (*Operophtera brumata* L.) defoliated deciduous woodland and fruit trees in 1948, Frit Fly (*Oscinella frit* L.) attacked oats in 1950 and 1951, Apple Fruit Moth (*Argyresthia conjugella* Zell.) destroyed many apple crops in 1950 and 1951, while Black Bean Aphis (*Aphis fabae* Scop.) so severely attacked bean and beet crops in south-eastern districts in 1952 that large-scale spraying operations had to be undertaken.

Considerable local damage was also done in 1949, by Diamond-back Moth (*Plutella maculipennis* Curt.) to turnips and swedes in the south-west, by Grass Aphid (*Metapolophium festucae* Theob.) and Mangold Fly (*Pegomyia betae* Curt.) in central districts; in 1950, by Beet Carrion Beetle (*Aclypea opaca* L.) in the east and Heather

Flea Beetle (*Haltica ericeti* Allard) in the south-east; in 1952, by Lettuce Root Aphid (*Pemphigus bursarius* L.) and Cabbage Stem Weevil (*Ceuthorrhynchus quadridens* Panz.) in the west and, in 1953, by Wheat Bulb Fly (*Leptohylemyia coarctata* Fall.) to winter wheat in the east.

On the other hand, populations of Antler Moth (*Charaeas graminis* L.), Heather Beetle (*Lochmaea suturalis* Thoms.), Cabbage Aphid (*Brevicoryne brassicae* L.) and Gout Fly (*Chlorops pumilionis* Bjerk.) of barley were remarkably low.

Non-indigenous insects occasionally found in nurseries included Azalea Leaf Miner (*Gracillaria azaleella* Brants), Rhododendron Bug (*Stephanitis rhododendri* Horv.), Rhododendron Whitefly (*Dialeurodes chittendeni* Laing), Gladiolus Thrips (*Taeniothrips simplex* Morison) and Chrysanthemum Gall Midge (*Diarthronomyia chrysanthemi* Ahlb.). All infestations were immediately eradicated, as were a few specimens of Colorado Beetle (*Leptinotarsa decemlineata* Say) found either on ships from European ports or associated with their cargoes and at least one Japanese Beetle (*Popillia japonica* Newm.) found in American military aircraft at Prestwick, Ayrshire in August 1953.

Major Developments in Research and Control

While many of the insect pests mentioned above have been, and still are, the subject of field observation and, in some cases, of experimentation in the hope of finding more adequate means of control, the following are the most noteworthy developments and achievements.

As the appended bibliography indicates, research on the insect pests of raspberries and on the insect transmission of certain virus diseases of this important crop has been a major project in recent years. This work still continues, forming an important part of the programme of the Scottish Horticultural Research Institute at Dundee. Recently, similar investigations relating to the potato crop have been added to the Institute's activities to meet an urgent need for more fundamental local knowledge on the transmission and spread of leaf-roll virus by the Peach-Potato Aphis (*Myzus persicae* Sulz.) in particular.

In this connection, mention should also be made of the work at the North of Scotland College where investigations on the distribution of Greenflies (*Aphididae*) in potato crops and on the bionomics of *Myzus persicae* Sulz. in particular have already produced interesting results likely to be of practical importance. In this area also special attention has been paid to the biology and control of the Turnip Root Fly (*Erioischia floralis* Fall.), the Turnip Mud Beetle (*Helophorus porculus* Bedel) and the Apple Fruit Miner Moth (*Argyresthia conjugella* Zell.).

At the West of Scotland College, detailed studies of the effects of the modern insecticides, particularly DDT and BHC, on the population-dynamics of the soil fauna have already produced results of outstanding scientific interest, while a quantitative analysis of the greenfly complex on strawberries in the Clyde Valley is the first of its kind in Scotland.

At the East of Scotland College, research on the bionomics of *Megastigmus* spp. and their parasites has been concluded, while work on insect pests of livestock continues. Experiments on the control of Carrot Fly (*Psila rosae* F.) have been conducted at all three Colleges and certain recommendations have been advanced which should enable growers to produce crops of carrots successfully.

Finally, in view of the importance of eelworms as pests of farm and garden crops in Scotland, mention should be made of the research, survey and advisory work being carried out at all three Agricultural Colleges and by the Department of Agriculture itself and, particularly, of the determined efforts by the West of Scotland College to find an effective means of controlling the Potato Root Eelworm (*Heterodera rostochiensis* Woll.). References to literature on eelworm problems are included in the appended bibliography.

INSECTS AND FOOD STORAGE PROBLEMS

The infestation of stored products in Scotland is, in general, similar to that in the rest of the United Kingdom with a few exceptions. *Ephestia elutella* Hbn. is not, however, the serious pest in Scotland that it is in southern England. It is only rarely found established in food stores, though more so now than in 1948. The major established pest in Scotland is the mite, *Tyroglyphus farinae* L., and many control measures (usually fumigations with methyl bromide) have been undertaken to control infestations of it in various grains. Another important endemic pest is the Spider Beetle, *Ptinus tectus* Boield., which is found in most stores and is omnivorous in its feeding, while the moth, *Ephestia kuehniella* Zeller, is the major pest in flour mills, bakeries, etc.

In addition to the well-established pests, there is a wide variety of insect pests introduced on various commodities. Some of these insects are capable of establishing themselves in unheated buildings in the country; others can survive in heated buildings, while yet others seem incapable of establishing themselves here. In the first group are such insects as *Plodia interpunctella* Hubn. and *Calandra granaria* L. and both are now established but also frequently supplemented by fresh introductions. In the second group are *Calandra oryzae* L. and *Tribolium castaneum* Herbst., both of which cause considerable damage in warm grain and can survive the winter in heated buildings. The latter species also attacks a wide range of commodities apart from grain and is our most frequent insect import. In the third group are such insects as *Necrobia rufipes* Deg. which rarely seems to persist even in warm buildings.

The major changes in stored products infestation work since 1948 are in the control measures applied. Methyl bromide is now the most frequently used fumigant and gas-tight fabrics are normally employed to cover stows, thus obviating the need for finding gas-tight rooms or buildings. Among the contact insecticides, pyrethrum still remains the one most used (because of its low mammalian toxicity) but DDT and BHC have now found wide application in food stores, particularly against residual infestations.

Fundamentally, the stored products infestation problem is a dynamic rather than a static one and the constant reintroduction of insect pests makes more difficult the work of reducing infestation in food premises. The trends are, however, favourable and it is to be hoped that by the time the Seventh Conference is held some notable progress will have been made.

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SOUTHERN RHODESIA

ENTOMOLOGY, 1948–1954

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Organisation

During the period 1948–1954 the Tsetse Control problem has become increasingly urgent and a separate Tsetse Fly Operations Branch of the Department of Agriculture was formed from part of the Entomological Branch early in 1952. Since then the staff of that Branch have devoted the whole of their time and energies to Tsetse Fly Control, leaving the Entomological Branch to devote itself mainly to agricultural entomology. For a short period in 1951–1952 the newly formed Game Branch was attached to the Entomological Branch but, after the secession of Tsetse Fly Operations, it was clearly misplaced and was, therefore, detached as a separate Branch.

These changes have necessitated a considerable increase in staff so that, in place of the total of two professional entomologists in 1948, there are now three entomologists on the Agricultural side and a director and five entomologists on the tsetse fly control side.

From 1948 to 1952 the Tobacco Pest Control Research Scheme, a government aided organisation with two entomologists, carried out investigations on pests and diseases of tobacco. In 1950 the Tobacco Research Board was established and took over control of the Tobacco Research Station at Trelawney. Later it established a new research station (Kutsaga) on the outskirts of Salisbury. At both of these stations work on the control of insect pests of tobacco has been carried out.

There has thus been a very considerable increase in applied entomological work in Southern Rhodesia during the six years. This has been due partly to the growing realisation throughout the world of the importance of the applied sciences and partly to the recent rapid development of Southern Rhodesia, the European population of which has increased approximately 70% in this period.

Research and Investigation

Tsetse Fly (*Glossina* spp.)

The increasing incidence of animal trypanosomiasis in the north-east corner of Southern Rhodesia led to a survey being made, in collaboration with the Portuguese, in the Portuguese territory adjoining this part of Southern Rhodesia, in 1948. *Glossina morsitans* Westw. was discovered to be widely but very sparsely distributed in that part of Portuguese East Africa. It was not until 1950 that any tsetses were found within Southern Rhodesia in this area. Since then there has been a gradual spread and tsetse can now be found up to 30 miles inside Southern Rhodesia. Throughout this area they are very sparingly distributed, however.

Mr. D. F. Lovemore has carried out intensive research into the ecological requirements of the tsetse fly, *G. morsitans*. At first in 1951/52, he undertook this research in a part of the Sebungwe District remote from interference by man. Owing to the growing urgency of the practical problem in the Urungwe District, however, he was transferred to this District and carried on research alongside more routine control work. One outcome of this work has been the discovery that *G. pallidipes* Aust. is now widespread in the Urungwe District where it was previously unknown, and the suspicion that it was more widespread in the Sebungwe District than was hitherto known has been confirmed. This species has also been found for the first time in the lower Sabi Valley. In the Urungwe District *G. pallidipes* has been found abundantly in places where extensive tsetse research was carried out by both entomologists and field officers several years ago. This earlier work included pupal surveys and thousands of pupae were collected and the flies bred out, all of them proving to be *G. morsitans*. Thus, this discovery can hardly indicate anything but an extension of range. In the Sebungwe and Sabi this species could, however, have been overlooked previously. In the Urungwe District, game destruction has been intensified since 1950, fences to restrict game and cattle movement have been built, and frequent and numerous injections of dimidium bromide have been given to cattle in the area in an endeavour to overcome the disease. These measures did not ameliorate the tsetse and trypanosomiasis position, however, and all cattle were removed from the Urungwe Native Reserve in 1952. Although in 1953 animal trypanosomiasis on the nearby Karoi farms decreased, there was still little, if any, sign of a retreat of *G. morsitans*, and at the end of 1953 recourse was taken to spraying selected areas from the air with BHC. The results of this preliminary work, which was completed in April 1954, have been disappointing. A bigger campaign is to start in July 1954, which will have the added advantage of taking place in the dry season when leaf fall reaches the maximum.

Maize Weevil (*Calandra oryzae* L.)

Dr. G. F. Cockbill carried out an investigation into the protection of stored maize against the attacks of *Calandra oryzae* and other insects by the use of DDT and BHC. He found that the use of 85 mgm. of technical DDT per square foot on the exposed surfaces of bags in maize stacks gave economic control of the maize weevil, *Calandra oryzae* L. A full account of this work has been published in the *Rhodesian Agricultural Journal*, **50,** No. 4 (July/August 1953).

Maize Stalk Borer (*Busseola fusca* Hmps.)

An occurrence of Maize Stalk Borer larvae in irrigated maize in early October 1950, led to the idea that perhaps the increase in the amount of maize grown under irrigation could lead to an extra generation of Stalk Borer moths with a consequent increase in numbers of the main generation in the early rainy season. An investigation of the bionomics of this insect was thus started late in the spring of 1953. Larvae reared from irrigated maize in two localities proved, however, to be *Sesamia calamistis* Hmps. Larvae were also bred in numbers from Napier Fodder (*Pennisetum purpureum*). The resulting moths proved to be *Busseola fusca*. This grass remains green and active through the winter and the amount grown is increasing. Whether an extra generation can occur either in irrigated maize or Napier Fodder has thus not yet been established. The investigation is being continued because if such a generation occurred, there would be a possibility of this leading to a dangerous increase in Stalk Borer population, where these crops are grown in proximity to main wet-season crop maize.

Army Worm (*Laphygma exempta* Wlk.)

An outbreak of Army Worm, *Laphygma exempta*, in January 1954, apart from the damage it did to crops, afforded an excellent opportunity of investigating the effects on it of various insecticides. It was found to be readily controlled by most synthetic insecticides including DDT, BHC, chlordane, aldrin, parathion, and toxaphene.

During and after the outbreak, which ended early in February, it was possible to make extensive observations on the bionomics of the Army Worm. Several hitherto unobserved features came to light and confirmation of several previously observed ones was obtained.

Larvae occurred in one of two clearly marked forms. These have previously been called solitary, and gregarious or crowded. These terms give a false impression since " solitary " larvae are really quite numerous. Samples indicate densities between 7 and 14 per square foot. These numbers are such, however, that they are never in danger of using up all available food. These larvae are prevailingly green in coloration, quiet in habits, comparatively slow in development and inconspicuous. They will be referred to as the PASSIVE form. The other form, which often uses up its entire food supply and moves elsewhere, is mainly black, vigorous in habits, quick in development and conspicuous, will be called the ACTIVE form. It is not gregarious because the larvae do not group themselves together but are merely forced, by the circumstance of their abundance, to be in close proximity.

It is hoped that it will be possible to keep the insects going during the winter and thereby obtain some information bearing on the ability of Army Worms to withstand the long Rhodesian drought. A brief summary of the results so far obtained follows. Most of the field and laboratory work was done by Mr. D. J. W. Rose, and it is hoped to write up the work in greater detail when all available information has been obtained.

Throughout Southern Rhodesia the rains at the end of 1953 were late in starting. At the Salisbury Experiment Station, where the detailed observations on Army Worm were carried out, less than 3 inches of rain fell up to the 13th December. Thereafter the rains were steady and constant and, apart from a dry period from 26th December to 1st January, inclusive, there was no period of more than four consecutive rainless days until 14th February. There followed a rainless period up to the 7th March, broken only by a light shower of 0·1 inches on 23rd February and a heavy downpour of 2·09 inches on 24th February. From 7th to 12th March was a moderately wet spell. Virtually no rain fell after this date.

The emergences of moths from the pupae are clearly correlated with rainfall. During a dry spell there are very few or no emergences. When heavy rains follow a dry spell there is a rush of emergences, gradually dying out over the succeeding days. This suggests that after completion of the necessary development period, which appears to be about 12 days, pupae are held up during dry spells and need the stimulus of rainfall before the moths emerge. Thus, early in January, from 6th to 11th, following the end of the late December dry spell, moths were seen in large numbers. They may have been present earlier but they had not been looked for as this was the first intimation we had of the imminent Army-Worm outbreak. A high proportion of the moths seen were found in heaps of discarded maize plants. Thirty moths collected from these heaps and subsequently analysed were found to comprise twenty-eight females and only two males. The possibility of such a sexual disparity was not foreseen and only became known after the main outbreak was over and time to sex the moths was found. During the outbreak of larvae, all of the active form, which followed the occurrence of these moths, rains were steady and there were no prolonged dry spells. The larvae pupated in moist ground which remained moist during the pupal period. Emergences of moths commenced in the field on 4th February and continued until the 15th, and in lesser intensity to the 19th. Thus the whole life-cycle of these moths was passed in moist climatic conditions. It will later be evident that not all moths of this generation emerged at this time. There was no sexual disparity in numbers in the moths emerging in this period. Of those analysed, 144 were female and 154 male. Of these, 95 females and 100 males were trapped on emergence in ground cages which precluded any differential catching effect. From these moths eggs were obtained after mating and after at least two days had elapsed. The caterpillars resulting from these eggs were mainly green and of the passive form and suffered fairly heavily from attack by parasites. The first moths were obtained from them in the laboratory on the 29th March. Larvae under completely natural field conditions kept pace approximately with the laboratory ones.

The heavy shower on the 24th February was followed by a small emergence of moths the following day. The wet spell commencing on the 7th March was followed by a large emergence of moths from the 9th to the 11th followed by progressively smaller daily emergences up to the 16th. A sample of these moths analysed comprised 67 females and 15 males of which 21 males and 3 females were caught in ground traps. This result is particularly surprising because these moths evidently came from caterpillars of the same generation as the early February moths which had shown even sexual distribution. They may have represented the later pupations of that generation but pupation could not have been more than a few days later. Moreover, it was found that these moths laid eggs the night they emerged and in three definite and other probable cases in cages in which only the female moths were found, eggs which subsequently hatched were found. Thus the disparity in sexes might not be a biological disadvantage since eggs laid by unfertilised females can develop parthenogenetically. Larvae found subsequently in the fields near where this delayed emergence took place, and presumed with confidence to be the offspring of these moths, developed, some into the active and others into the passive larval form. These observations indicate that active-form larvae give rise in part to moths which lay eggs in their emergence area and which may give rise to either larval form depending on the conditions in its habitat, and very likely also to moths which normally migrate before egg-laying. These latter moths can, however, also lay eggs in the emergence area if they are prevented from migrating—in other words migration is not an essential precursor of egg-laying.

The degree of parasitism in these larvae was low. No reason for this is evident. At this time also reports of active-form larvae were reported from several farms in the neighbourhood of Salisbury. One of these was examined and the active-form larvae appeared to be in abundance similar to that during the outbreak. Passive-form larvae were found in an adjoining field. These were generally smaller than the active ones, which would probably indicate that the larvae, though hatching at the same time as those of the active form, developed more slowly. Their habits also differed as they seemed to spend most of their time at the bases of the grass plants and were sluggish. By contrast the active-form larvae occurred all over the plants and were very vigorous in movement and " irritable ", and being also more numerous were much more conspicuous. These differences were apparent also in the two larval forms found contemporaneously at the Salisbury Experiment Station.

A further significant feature was that at the time of the Southern Rhodesian outbreak in January there were no reports of Army Worms in the Union of South Africa. Following the normally sexed and delayed ovipositing moths of early February in Southern Rhodesia a large larval outbreak occurred in S. Africa late in February. The early February emergences at the Salisbury Experiment Station were very numerous; ten square yard samples of ground produced 175 moths. A sample of 200 larvae caged under as natural conditions as possible produced 106 moths. This indicates that there was no unduly great mortality of fully grown larvae or pupae below ground. Hence, if all these moths had laid eggs in the areas of their eclosion there should have been an even bigger outbreak of Army Worm than the January one. In actual fact only passive-form larvae were in general found and these were never sufficiently numerous to attract the attention of anyone other than the entomologists who were looking for them, except for one report in the south of Southern Rhodesia which probably referred to active-form larvae. The evidence is thus strong that most of these moths migrated south. Further, in each case observed where there was a preponderence of female moths an outbreak followed in the area of occurrence of the moths. Such preponderantly female emergences occurred after somewhat protracted dry spells and there is evidence that some at least of the eggs laid developed parthenogenetically. The moths in the predominantly female emergences were smaller than those in evenly sexed emergences. We now think that in subsequent years following a dry spell we must look for Army-worm moths and if we find them and they are predominantly female we can expect an Army-worm outbreak. After some initial investigations it was found easy to distinguish the sexes since while the males are brightly variegated the females are almost concolorous.

It has often been stated that *Laphygma exempta* moths choose for preference low-growing sweet grass weeds on which to lay their eggs. This was not so for the early February or the March moths. Egg batches were found at various heights up to 7 ft. on maize plants, even when there were but few grass weeds below. At this time the maize plants were too old to be palatable for the young larvae and they were not in fact attacked. In one instance eggs were found on a maple leaf, on an isolated young tree with lawn grass below.

It was observed that immediately after hatching the caterpillars fell from the leaves on silken threads even without disturbance. So marked was this habit that, unless an egg mass was visited just after hatching, it was difficult to find the young larvae at all. It was thought they secured a certain amount of dispersal by being blown by the wind on their threads. Generally speaking, early in the wet season, wherever they landed they would find suitable grass to feed on. Where the eggs were laid at that time would have little significance in the bionomics of the species. Later, young grass is not so readily available and therefore many of the young larvae would probably die. This may in part explain why no outbreak followed these February hatchings, which in any case suffered heavily from parasites, and also why only a small outbreak restricted to pastures with tender grasses followed the March hatchings. We have made a number of other observations, some of which are continuing, and have a number of other suspicions, such as the possibility that larvae hibernate below ground. Measurements have been made of passive and active larvae in all stages, and their growth-rates under varying conditions have been measured. Differences in behaviour of the two kinds of larvae have been observed. Several different parasites, including a tiny egg parasite, await identification. All these things we hope to consolidate into a coherent account for publication later.

Cotton Pests

During the current season the Cotton Research and Industry Board have arranged concurrent trials of insecticides for the control of cotton pests at about 20 different points in Southern Rhodesia. The main insecticide used was DDT emulsion at the rate of 1½ lb. technical DDT per acre. This insecticide was to be applied at approximately 10-day intervals depending on weather conditions, the first application being made when the first flowers opened. With the first application BHC emulsion at the rate of 8 oz. gamma isomer per acre was to be applied and repeated subsequently if aphid infestation was apparent. As at the Salisbury Experiment Station infestation by Red Bollworm, *Diparopsis castanea* Hmp., became apparent before flowering, the first application of insecticides was brought forward. So far it seems that excellent control of Red Bollworm has been achieved, and also of aphis (species not yet determined). A mite, not yet identified, has become fairly numerous but does not seem to have done much damage. At the Sabi Valley Experiment Station, a mite, not necessarily the same species, became sufficiently numerous for an application of malathion to be made for its control. The results so far obtained are thus encouraging but require proper analysis for the Colony as a whole before any definite conclusions can be made. It is for instance noteworthy that the climate of Salisbury is by no means ideal for the culture of cotton and it might also be that *Diparopsis castanea* is easier to control there than elsewhere.

Scale Insects and Aphids

Soft scales and Aphids cause a great deal of trouble, particularly on citrus and to a lesser extent other fruit trees. Dieldrin has recently become available and trials of its use as a tree-banding material have been made. The first results are very promising and a band about 6 inches wide painted round the trunk seems to keep ants away from the trees for at least three months. During this period the pests, (*Coccus hesperidum* L., and *Toxoptera citricidus* Kirk and *Anuraphis persicae-niger* Smith have been tested), virtually disappear due to attack by their natural enemies. These are various Coccinellidae, Syrphidae and Hymenoptera which become conspicuously plentiful about the treated trees. The use of parathion as a spray, either alone or to supplement dieldrin seems neither necessary nor desirable and in some cases definitely seems to have led to an increase in the *Coccus hesperidum* population.

Locusts

A few colonies of *solitaria-* or *transiens*-phase Red Locusts, *Nomadacris septemfasciata* Serv., have been found and in one of them *Locusta migratoria migratorioides* Rch. and Fairm. occurs also. The best known of these colonies, which was discovered in 1951, seems to remain steady from year to year. It seems that it must have been in the area at least since 1942 when the last swarm was reported from that area. Due, no doubt, to the active control measures taken by the International Red Locust Control Service in the outbreak areas, no swarms of Red Locusts have been reported in Southern Rhodesia since 1943.

TANGANYIKA

A SUMMARY OF ENTOMOLOGICAL PROBLEMS

By G. Swaine

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In Tanganyika the basic pattern of agriculture, which has a considerable influence on the type, intensity and solution of pest problems, remains much the same as reported at the last Conference (1). Over the greater part of the Territory, food crops of maize, sorghum, millet, rice, bananas, groundnuts, pulses and cassava and cash crops of cotton, cashew, coconuts and castor are mainly grown by peasant farmers in a patchwork cultivation of small plots. In the two highlands areas, centred around Moshi and Arusha in the north and around Iringa in the south, the production of cash crops such as maize, wheat, coffee, seed beans, pyrethrum, tea and tobacco on farms which are becoming increasingly mechanised is largely in the hands of Europeans with the exception of coffee, of which African production greatly exceeds that from European farms. The Territory's most important cash crop, sisal, is produced chiefly in the lowlands of the Tanga and Eastern Provinces.

The advent of the synthetic insecticides has given real hope of the control of many crop pests and the main endeavour in the field of economic entomology in the Territory over the past seven years has in fact been concerned with methods of chemical control appropriate to the local conditions. In peasant farming the emphasis is upon the development of simple control measures with cheap, fool-proof applicators. The shortage of readily available water in many of these areas is a great barrier to the development of any spraying technique and attention has therefore been focussed on the application of dusts. A paper describing a cheap and simple duster suitable for use by peasant farmers is to be published shortly (2). In the European farming areas increasing interest is being taken in the application of sprays both from the ground and from the air. Some assistance in this work, particularly with seed bean pests, has already been given by the Colonial Insecticide Research Organisation, and its continued help with pest problems in other crops is now assured by the setting up of a Unit on the Ilonga Agricultural Station near Kilosa in Eastern Province.

Pests of Native Food and Cash Crops

Stalk-borers of Graminaceous Crops

The Noctuid, *Busseola fusca* F., is the most destructive borer in the Territory, being particularly troublesome in the first plantings which are made with the onset of the rains at the end of the dry season. This normally lasts from July to November or December with local variations. Biological observations have shown that the moth is attracted to oviposit on young plants about 18 days after germination and continues so doing for a further month. A second generation commences 50-60 days after the first one but is smaller in numbers and normally has little real effect on the plants which by this time are well established and nearing maturity.

Single applications of insecticide into the funnels of the young plants have proved useless in this Territory where strong sun and heavy rains are responsible for the rapid disappearance of the toxic ingredient. Experiments now planned are aimed at covering the period of emergence of young larvae of the first generation with four or five weekly applications of a 2·5% DDT dust.

Very good control of the two less important Pyralid borers, *Proceras argyrolepida* Hmps. and *Chilo zonellus* Swinh. as well as the Anthomyiid fly, *Atherigona indica* Mall. has been obtained on short-term sorghums by five weekly applications, at 10 ozs. per 1,000 plants, of a dust containing 2·5% DDT plus 5% toxaphene; recent work (3) has indicated that a dust containing 1·5% gamma BHC would be satisfactory for the control of *Atherigona.*

Army Worms

Army-worm attacks usually coincide with the appearance of young maize, sorghum or rice planted on the early rain in December or January and may be of purely local interest or occasionally, as during the past season, cover the entire Territory. Provided adequate rain is received, sorghum beyond the age of one month is able to recover by the production of tillers; maize and rice are not so fortunate if attacked at this early stage. Good control has recently been obtained over 300 acres of native crops by the prompt application of a dust containing 10% DDT plus 3% gamma BHC but the economics of such control are by no means clear. Delay caused by the need for replanting may or may not be important depending on the ensuing weather conditions. Work on the meteorological and other factors leading to outbreaks is urgently needed together with an investigation into the economics of control in different rainfall areas.

Cotton Insects

Cotton-growing in the Territory is mainly carried out in the area around Lake Victoria and inland in Eastern Province, the two areas being completely separated by the extensive central plateau lands of Western and Central Provinces. A subsidiary area of different entomological interest is present in the south near the border with Portuguese East Africa.

Until recent years cotton yields in the Lake Province were seriously reduced by Jassid, *Empoasca* sp. Resistant strains have now been developed by Empire Cotton Growing Corporation staff and the distribution of successive waves of seed to native growers has become an established practice. Cotton stainers, *Dysdercus* sp., in the more marginal cotton-growing areas cause considerable trouble; attempts to improve on a control method using arsenite/sugar bait flicked on to the plants have not yet proved successful and it is intended to carry out further work with the newer synthetics. American Bollworm which has rarely been a pest of importance in the Lake Province may become troublesome with the increasing cultivation of compact-headed sorghums. Considerable build up of the insect on such sorghum types and later migration to cotton has been recorded during the past year.

In the Eastern Province the entomological problem is mainly with American Bollworm which has steadily become more important with the increase of maize-growing since the end of the war. Spectacular control has been obtained under experiment station conditions by officers of the Empire Cotton Growing Corporation. Treated plots over the past 2 years have yielded approximately 900 lb. of seed cotton per acre compared with 40 lb. or less from the controls. In these experiments a 10% DDT plus 3% gamma BHC dust was applied 5 to 7 times during the season at the rate of 10 to 16 lb. per acre per application. Such low yields as have been obtained in the controls in these trials are not typical of native cotton growing where average annual yields of approximately 300 lb. occur, and the precise factors accounting for such figures in experimental work require investigation. In the field the main problems are the assessment of the incidence of bollworm in different areas and under different growing conditions to determine whether control measures should be prosecuted in native holdings, and secondly the making available of cheap insecticide and applicators for purchase by the peasant farmers.

Action against the possible northward spread of Red Bollworm, *Diparopsis castanea* Hmps., from areas bordering Portuguese East Africa was taken about 6 years ago by the creation of a quarantine belt 140 miles wide separating Southern and Eastern Province cotton. A species of *Diparopsis* formerly thought to be identical with that of cultivated cotton and found on bolls of a related wild plant, *Gossypioides kirkii*, which has a discontinuous distribution through Southern and Eastern Provinces, has now been identified as a separate species (4). However, the possibility of *D. castanea* being able to bridge the quarantine belt by breeding on *G. kirkii* still threatens and investigations on the problem are now being planned.

Coconut Pests

Investigation on a species of Coreid bug* which causes nutfall and gummosis of coconuts in the East African area (5) is being carried out under the recommendations of a co-ordinating committee with representatives from Zanzibar, Tanganyika and Kenya. Whilst direct control using hand sprayers has been obtained on an isolated area in Zanzibar, the mobility of the insect and the regular production of attractive flowering and fruiting branches mitigate against such measures over a large area; the patchwork cultivation adopted by the peasant grower, it is feared, would not lend itself to the use of mechanised spraying equipment at an economic cost. Some hope is entertained of efforts to encourage the predatory ant *Oecophylla longinoda* (Latr.), which nests in the crowns of the palms, by banding against the antagonistic ground-dwelling forms *Anoplolepis* and *Pheidole*.

Coconut beetle, *Oryctes monoceros* Ol., continues to be a pest of some importance; local efforts to cut down and bury infested palms appear to have brought about reduction in the amount of damage but such physically exhausting measures are not favoured by the indigenous population and very slow progress is being made. The introduction of parasites might prove a useful measure but present staffing prevents this aspect of the problem receiving the attention it deserves.

Pests of Leguminous Crops

One of the main insects damaging native legumes, dwarf beans and cowpea, is the leaf-eating Galerucid beetle, *Ootheca bennigsenni* Wse. Preliminary trials with 2·5% DDT and dieldrin dusts applied to the young plants have shown that the insect could be readily controlled although a systematic enquiry into the most appropriate time of year to carry out control measures and the number and frequency of applications has still to be made. Much loss is occasioned, particularly in the Western Province, by the depredations of blossom beetles, *Mylabris* sp. The appearance of the adult beetles in mass numbers is restricted to a relatively short period of the year and it would appear that a chemical control would be possible.

Cashew Pests

Exports of unprocessed cashew nuts have risen during the past 10 years from 2,000 to 10,000 tons annually, most of this being produced by native growers in the Southern Province of the Territory. Recent surveys have shown that considerable damage is being caused to fruiting branches by a new species of *Helopeltis* bug. The fact that this insect has been caught in a number of widespread areas on the mainland and also on Mafia island about 20 miles from the coast indicates that it is not of recent introduction. At the present time the scattered nature of cultivation precludes the possibility of organised spraying but the recent formation of a Cashew Growers Association affords hope that cultural improvements will follow and facilitate the use of spraying equipment.

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* This species which has hitherto been referred to in the literature as *Theraptus* sp. is now known not only to be a new species but to belong to a new genus, the descriptions of which are shortly to be published by Mr. E. S. Brown.—*Ed.*

Coffee Pests

The important coffee pests in the Territory are the Pentatomid bug, *Antestia lineaticollis* Stål., the white Lamiid borer, *Anthores leuconotus* Pasc., and the cherry borer, *Stephanoderes hampei* Ferr. Following on the work of Notley (6) former control measures against *Antestia* involving arsenite/sugar baiting and pyrethrum dusting have now been abandoned in favour of spraying with DDT emulsion. Extensive use is now made of the insecticide, not only by European coffee farmers but also by the native farmers in the Kilimanjaro area through the organisation of the Kilimanjaro Native Co-operative Union. The control of *Anthores*, which is primarily a pest in the lower coffee-growing areas, is by no means easy. Removal of the larvae from their burrows with a piece of wire, fumigation *in situ* with a mixture of ethylene dichloride and carbon tetrachloride, and uprooting and burning of infested plants, have all been tried in the past with varying success. The application of residual formulations of the more modern synthetics to the lower parts of the stem is now being investigated (7). Cage experiments indicate that a 2% dieldrin emulsion formulated with a proprietary resin will give satisfactory kill of the female beetle and remains toxic for at least 60 days. This insecticide proved significantly better than DDT and toxaphene. Field experiments based on the above information have shown the need for methods of assessing infestation other than the traditional one of exposing the insect by removal of the bark and wood and various methods based on the amplification of sound produced by the chewing larvae are now being tried out. *Stephanoderes* borer is restricted at the moment to native coffee grown in the Bukoba area, which borders on Uganda. Efforts to control the pest by campaigns for the removal of fallen infested cherry have not been satisfactory and experiments are now to be carried out using lindane insecticide.

Other coffee pests, of minor importance, are green scale, *Coccus africanum* Newst., leaf miner, *Leucoptera coffeella* Guer. and a recently observed mite (8) *Hemitarsonemus latus* Banks. There is some belief that increases in numbers of these insects in recent years may be correlated with the widespread use of DDT for *Antestia* control.

Bean Pests

Investigations on the insect complex attacking seed beans in the field have been carried out over the past two years by a member of the Department staff especially posted to Northern Province. Broadly speaking the damage can be classified as due to Lepidopterous pod borers and/or defoliators, to Hemiptera which suck the seed, and to Coleoptera which feed mainly on the blossom and young pods. Included in the Lepidopterous pests are *Heliothis armigera* Hbn. (pod borer), *Phytometra orichalcea* F. (defoliator), *Prodenia litura* F. and *Laphygma exigua* Hbn. The important Hemiptera are the Coreid bugs, *Acanthomia horrida* Germ. and *A. tomentosicollis* Stål., and the Pentatomid, *Nezara viridula* L. The blossom beetles are mainly Meloid beetles, *Mylabris* spp.

Under-leaf spraying with a locally adapted sprayer using ¾ lb. of actual DDT in 15 gallons of emulsion per acre gave good control of a Lepidopterous outbreak in 1953, whilst good control was stated to have been obtained against almost mature American Bollworm larvae by aerial spraying with a 1·9% DDT emulsion in an outbreak the previous season (9).

The Bruchid beetles, *Acanthoscelides obtectus* Say, *Callosobruchus chinensis* L. and *C. maculatus* F., cause some damage to beans in the field but are more particularly important in storage. The seriousness of these insects has long been appreciated by some of the European farmers in the Northern Province producing seed beans for export and such control measures as carbon disulphide fumigation of the crop immediately after harvest and the admixture of an 0·05% gamma BHC dust formulation after grading are now being carried out by them. Difficulties of finding markets for seed beans, owing to overseas import restrictions, are leading to the development of a trade in white haricot beans for canning; in this connection canners' requirements in respect of Bruchid-free consignments are necessitating the wider control of the pests and an admixing technique using 6 ozs. of an 0·05% lindane formulation per 200-lb. bag has now been accepted by the majority of the canning firms in England.

Tobacco Pests

The two main groups of pests with which tobacco growers have to contend are eelworm, *Heterodera marioni*, and cutworms, *Euxoa* spp. and *Laphygma exigua* Hb. It has not proved possible to do any critical work on eelworm but some useful preliminary information on the control of cutworm has been obtained (10). The main cutworm damage is done to the seedlings in the seed beds and when they are young transplants in the field. Some relief from attack in the field can be obtained by weed control well before planting; inter-row weeding after planting out results in the activities of the cutworms being focussed on the tobacco seedlings. Insecticide experiments carried out in 1951 indicated that control could be obtained by the application of a 10% toxaphene dust to the soil around the plant at transplanting time; application of a BHC/bran bait at the rate of 12½ lb. of 3% gamma BHC per acre was required 40 days after the toxaphene treatment. Soil application of BHC was found to be phytotoxic to tobacco seedlings. Further work using aldrin as a soil insecticide is to be carried out during the coming year.

Sugar-cane Beetle

A special study of the Rutelid beetle, *Cochliotis melolonthoides* Gerst., by a former entomologist, W. F. Jepson, resulted in the working out of a control method by the application of 1 cwt. of Agrocide 7 per acre to the planting troughs at the time of planting the seed pieces. A plot treated in this manner yielded 2,785 tons of cane in 1950 as compared with a previous crop of 993 tons in 1948. Some doubt has been expressed as to the continued protection of ratoon crops by BHC and attempts to obtain the added persistence are being made in experiments using 2·5% aldrin dust applied at 1 cwt., ½ cwt. and ¼ cwt. per acre.

Grain Storage

Short-term storage of maize in bags is carried out by a Department of Government with stores of 3,000 or more tons capacity at six strategic centres. Pest control measures over the past few years, mainly directed against *Calandra oryzae* L., have included the direct admixture of BHC dust at grain buying centres, the building of large, compact stacks in which insect infestation is reduced to the peripheral bags, heavy applications of 0·5% gamma BHC dust to the outside of the bags as the stack is built and methyl bromide fumigation. Whilst *Calandra* is by no means the problem that it used to be, some cheap and reliable control is required of *Ephestia cautella* Wlk. and *Silvanus surinamensis* L. which appear to have become more numerous during recent years.

The long-term storage of grain for famine relief has been investigated over the past two years using the underground pit storage method developed in the Argentine during the war (11). In this method reasonably dry, infested grain is sealed down in an airtight, water-vapour-proof pit, depletion of oxygen and accumulation of carbon dioxide resulting in the death of the contained insects. In the three 120-ton experimental pits in this Territory, maize of a maximum moisture content of 13·5% was stored for 379, 446 and 466 days, respectively, and was found to be in excellent condition when removed. The construction of a number of 1,000-ton pits, divided by cross walls into 250-ton compartments to facilitate piecemeal delivery, is now being carried out. Additional trials using high moisture content maize are planned for the current year.

Apart from Government organisations very little insecticidal control of stored-products pests is carried out in the Territory. It is hoped this year to interest commercial firms in the packing of BHC dust in small, dispensable containers for retail to the African grower for direct admixture with the food grains produced by himself and stored on his own premises.

Discussion

In European farming areas and where native growers combine in a Co-operative concerned with the cultivation of a highly remunerative cash crop, coffee being the particular example in Tanganyika, ample funds are available for pest control measures and it can be assumed that such practices will be extended. Elsewhere control of insects in stored food grains has been adopted by a Government Department and Native Authorities.

The individual native farmer cultivating small plots of food and cash crops has little surplus capital to expend on insecticides and applicators: aggregation of native agriculture, which would encourage the organisation of pest control measures, appears unlikely. Under these conditions cheap apparatus, robust and simple to operate and maintain, is essential in the first instance. Trials with such equipment, based upon biological information obtained from both agricultural stations and native holdings, may then demonstrate whether or not the extension of chemical control to native agriculture is an economic proposition. Work on these lines is in progress with American Bollworm on cotton and with maize stalk borer.

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TRINIDAD

REVIEW OF ENTOMOLOGICAL WORK CARRIED OUT BY THE DEPARTMENT OF AGRICULTURE, 1948–1953

By R. G. Fennah

Coconuts

Tests made by the Department of Agriculture of a small range of equipment for spraying scale insects and ants on high coconut trees showed that only a large machine with a normal working pressure of 400 lb. gave adequate cover. White oil emulsion fortified with parathion, or an emulsion alone, gave satisfactory control. It was established experimentally that the Palm Weevil (*Rhynchophorus palmarum*) is capable of carrying coconut-trunk débris infected with the nematode, *Aphelenchoides cocophilus* from one tree to another, though it is not established that this insect is the only means of transmission.

Sugar-cane

Measures for the control of froghopper (*Aeneolamia varia* (F.)) by the use of chlorinated hydrocarbon insecticides applied to the soil surface around the base of the stool have become standardised during the period under review. The material is applied as a dust, delivered by hand-operated dusters of knapsack type. BHC, diluted with ground limestone of local origin, is generally employed, though one estate uses chlordane diluted with a dust derived from reject crushed hollow clay tiles. An effective scouting organisation is regarded as essential, and on one estate at least the prior removal of weeds by pre-emergence spraying with weed killer is considered an important feature of the operations. It was established some years ago that adult froghoppers could be completely suppressed by dusting from a helicopter, but the treatment had virtually no effect on the nymphs, with the result that the adult population returned to normal after three or four days.

Cacao

It was found that spraying of cacao trees with dilute BHC suspension gave complete control of cacao thrips (which has two peaks of abundance during the year), but that in the sprayed areas no measurable benefit was subsequently noted as compared with the control. Cacao beetle has not been considered sufficiently abundant in estates in Trinidad to merit chemical control. At the Experiment Station of the Cacao Research Scheme populations are held down to a very low level by the use of a durable twig-bark cover of lead arsenate plus a trace of chlorinated hydrocarbon and a linseed-oil sticker.

Citrus

The presence of fruit-puncturing moths has been established in Trinidad, but the insects appear to cause appreciable injury only to oranges, and this not at a time when the main crop is on the trees. Ants, the presence of which is characteristic of unthrifty trees, have proved to be easily controlled by chlordane applied as a spray to the nest. Flea beetles on nursery stock are controlled by repeated applications of chlorinated hydrocarbons.

General

Chlorinated hydrocarbon insecticides have been found effective against mole crickets. Prior to the appearance of aldrin and dieldrin, it was found that ants in general, and most important among these, the Parasol ant, could be effectively controlled by spraying the entrances of the subterranean nest with chlordane.

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REVIEW OF ENTOMOLOGICAL WORK AT THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, 1948–1954

A study of cacao virus disease, which closely resembles some of the less virulent strains of ' swollen shoot ' in West Africa, was continued by T. W. Kirkpatrick. Five species of mealybugs are known to be vectors through only one, *Planococcus citri* (Risso), is of any importance. No alternative host plants of the virus have been found. (*Bull. ent. Res.*, **41,** 99–117, 1950. Report on Cacao Research, 1945–51, I.C.T.A., Trinidad (1953).)

The life-histories of the mealybugs occurring on cacao, and their parasites and predators, have been investigated. (Report on Cacao Research, 1952, I.C.T.A. (1954).)

Work has begun on the minor pests of cacao. An account of the leaf-eating Lepidopterous caterpillars has been prepared for the 1953 Report on Cacao Research. A new internal Cecidomyiid parasite of Aphids has been found : it is abundant in *Toxoptera aurantii* Boyer on cacao and less common in other species of Aphids.

Numerous instances were reported of moths' eggs laid on the exterior of commercial aircraft arriving in Trinidad from the south. Most of them were *Laphygma frugiperda* S. & A. though some, not bred to maturity, were probably a *Phytometra* or related genus. (*Nature*, London, **164,** 60, 1949.)

E. McC. Callan, who left the College early in 1951, continued his studies on the preying habits of wasps (*Proc. 8th Int. Congr. Ent.*, Stockholm, 1948 (1950)), and on Embioptera and their parasites (*Trans. 9th Int. Congr. Ent.*, Amsterdam, 1951 (1952)).

R. G. Fennah, who was appointed Entomologist to the Cacao Research Scheme at the end of 1951, is working on the ecological relation between pests of cacao and their host plant. Papers on the digestion of carbohydrates by the Cacao beetle (*Steirastoma breve* Sulz.) and the distribution of its attack in relation to various ecological factors will be published in the 1953 Report on Cacao Research.

During the period under review Mr. Fennah's published work has included the following :—

General

1949. Field Tests with DDT against insect pests of food crops in the Leeward Islands. *Trop. Agric. Trin.*, **25**, 1–12, 45–52.
1949. Autecological notes on three species of *Aeneolamia* (Homoptera : Cercopoidea). *Ann. & Mag. Nat. Hist.*, **12** (2), 703–726.
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1951. Termites : their life history and measures for their control. *Proc. Agric. Soc. Trinidad & Tobago*, **51**, 97–113.
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Taxonomic

1949. New Tropiduchidae from Melanesia (Homoptera : Fulgoroidea). *Ann. & Mag. Nat. Hist.*, **12** (2), 161–173.
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1952. A revision of *Bladina* Stål (Nogodinidae : Fulgoroidea). *Ann. & Mag. Nat. Hist.*, **12** (5), 910–928.
1953. A new froghopper from Bolivia (Homoptera : Cercopoidea). *Proc. Biol. Soc. Wash.*, **66**, 51–52.
1953. Revisionary notes on Neotropical Monecphorine Cercopoidea (Homoptera). *Ann. & Mag. Nat. Hist.*, **12** (6), 337–360.

M. H. Breese, who joined the College Staff in 1951, has been working on the conditions governing the infestability of paddy, especially by the small strain of the rice weevil, *Calandra oryzae* (L.).

As part of their course of study at I.C.T.A., Colonial Office post-graduate entomology students undertake an investigation on some entomological problem, on which they write a report. Subjects studied during the period under review include the following :—

J. L. Gregory. A study of *Griburius triangularis* Suffr., a Cryptocephalid beetle that feeds on *Cordia macrostachya*, and its suspected relationship with *Kapala furcata* F. (Hym. Eucharidae). Although it was ascertained that no obligatory relation between the two insects existed, several interesting observations on the ecology of both species were made.

A. J. Jones. The bionomics of the Arrowroot Leaf-roller (*Calpodes ethlius* Cram.).

P. B. Cornwell. Ecological studies on Ants attending Homoptera on cacao.

R. M. Lister. A survey of pests of Citrus.

D. J. Taylor. Biological investigations on predacious Syrphidae.

T. J. Crowe. A study of the life-history of *Pycnoderes atratus* (Dist.) (Hem. Miridae) in relation to light intensity and the water balance and nutrition of its host plant, *Commelina*.

I. J. Wyatt. A study of the possible insect vectors of Chlorotic Streak disease of sugar-cane.

UGANDA

REVIEW OF AGRICULTURAL ENTOMOLOGY, 1948–1954

By A. P. G. Michelmore

Owing to its good climate and soils, Uganda is one of the richest colonies in agricultural resources. The part that entomology can play in the development of such resources is always small at first but increases greatly as development proceeds. In recent years many factors have both increased the need for entomology and made its practical results easier to apply in Uganda. These factors include an increase in population, a rise in standards of education, the development of secondary industries, with a consequent growth of towns and bigger demands for labour and food, the co-operative movement, high prices of many agricultural products, trials of new mechanised and grouped methods of farming, and, last but by no means least, the discovery of new persistent insecticides not very toxic to human beings. There is, therefore, a growing need for routine services and for extension as well as for research work. Unfortunately staff has been difficult to obtain, and the Entomological Section has been below strength for the full period. The gap has only partly been filled by the generous loan of a Field Officer by the Colonial Insecticides Research Unit and by the establishment of the central research station of the Empire Cotton Growing Corporation at Namulonge.

The development of agriculture and entomology constantly shows the value of the great mass of information collected over many years by H. Hargreaves and his assistants. This information is collated in the form of museum collections of specimens, files of notes and paintings, and in the entomological sections of Tothill's ' Agriculture in Uganda ' (1940). To remain useful, all this collecting and cataloguing of individual specimens and observations must be kept up to date. This work, being routine, is liable to be pushed aside by more urgent calls, and it is now a matter of concern that it should continue and that arrears should be worked off.

Other routine work which is done includes a moderate amount of advisory work, which could be greatly extended to the benefit of the country; plant quarantine work, which grows in importance with increasing air traffic but has not yet necessitated special staff; the collection and issuing of locust reports, happily not onerous of recent years; destruction of pests on research stations and elsewhere; an annual course in agricultural entomology to students of Makerere College; sampling of crops and produce to give statistics on pests and the damage done, a service which should be greatly enlarged; and, finally, dealing with requests for specimens and information from specialists in other countries, requests which are few in number, but which individually take some time to execute.

The biggest research project undertaken during the period under review is the double one of the insecticidal control of *Lygus vosseleri* Popp. on cotton and a general study of methods of applying insecticides to tropical peasant crops. In the course of the latter the biggest collection of spraying and dusting machinery in East Africa has been made and studied. The new technique of low volume spraying has been proved to be effective under tropical conditions against a number of pests. It has been proved that *L. vosseleri*, believed to be the worst pest of our most valuable crop, can be controlled with insecticides, but this has raised further problems of the reactions of the host-plant and of other pests and diseases to the control operations. These studies are being continued by Mr. T. R. Jones and Mr. H. D. Mubbiru in close collaboration with other workers in East Africa and Britain.

The second research project is a study of the Rootknot Eelworm, *Meloidogyne*, in relation to tobacco. Mr. T. E. T. Trought has found that the eelworm is not confined to damp valleys or seedbed sites but is widely spread over the countryside in many areas in semi-natural vegetation and may well be native. In spite of this fact, injection of seedbeds alone with soil fumigants gives good results. The practical application of this method is hindered by low standards of seedbed maintenance in many places.

Amongst minor investigations the following are worth noting:—

(i) Kagera Dwarf Locust, *Faureia milanjica* Karsch. Seasonal history and habits worked out; found not to be as serious a pest as feared; campaigns of extermination would need collaboration with Tanganyika and Ruanda.

(ii) Banana Weevil, *Cosmopolites sordidus* Germ. Abortive attempt at introducing predators; preliminary trial of control with aldrin promising.

(iii) Termites. Work started by Mr. W. V. Harris when Senior Entomologist continued by him after transfer to the new Colonial Termite Research Scheme.

(iv) Food Storage. Many modifications suggested for the new grain-conditioning plant at Jinja; admixed diatomite dust proved a useful preservative for beans and maize; storage of maize cobs in cribs proved practicable if done properly and sheaths left intact; studies of early infestation of maize and of moisture content and insect damage to dried tubers.

(v) Cereal Stem-Borers. Statistics of damage collected; problem found to be complex, involving Lepidoptera (*Busseola*, *Sesamia* and *Chilo*), Diptera (*Atherigona* and various Chloropidae) and rots; more intensive research projected.

(vi) Coffee Pests. Insecticidal control becoming necessary, but good results difficult to get with *Hypothenemus* (*Stephanoderes*), and *Antestia* control still not perfected; statistics of damage collected; *Corioxenos* (Strepsiptera) found incapable of controlling *Antestia*; intensive work on pest-disease complex needed.

The following reports and papers have been published, but much of the work of the section has not yet appeared in print.

HARRIS, W. V., 1948, Report on a trial with DDT and BHC for the protection of timber against termites. *E. African Agric. J.*, **14**, 49–50.

HARRIS, W. V., 1948, An international meeting on infestation of foodstuffs. *E. African Agric. J.*, **14**, 79–80.

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MICHELMORE, A. P. G., 1950, Report on coffee pests and diseases; in *Dept. Agric. Uganda, Rec. Investigations* No. 1, 1948–1949, 31–46. Entebbe.

MICHELMORE, A. P. G., 1952, General Progress Report; in *Dept. Agric. Uganda, Rec. Investigations* No. 2, 1949–1950, 4–22. Entebbe.

MICHELMORE, A. P. G., 1954, Report of the Section of Entomology; in *Dept. Agric. Uganda, Rec. Investigations* No. 3, 1950–1952, 39–93. Entebbe.

ANON., 1953, Storage of agricultural produce. Entebbe.

The help of the Commonwealth Institute of Entomology is gratefully acknowledged. With entomology increasing in importance, closer contacts between the various entomologists in East Africa are needed and are being fostered.

WEST AFRICA

A REVIEW OF THE WORK CARRIED OUT BY THE ENTOMOLOGICAL SECTION OF THE WEST AFRICAN INSTITUTE FOR TRYPANOSOMIASIS RESEARCH, 1948–1953

By T. A. M. Nash, O.B.E., D.Sc. (Lond.)
Chief Entomologist and Deputy Director, W.A.I.T.R.

For six consecutive years a continuous study was made of the tsetse fly, *Glossina palpalis* (R.-D.), along 2,400 yards of stream, situated near Kaduna, N. Nigeria (Nash & Page, 1953). Some of the findings are given below.

In the dry season, streams tend to dry up, apart from a few pools, and in severe years a pronounced micro-climate occurs at 4 inches above wet sand. The surviving tsetse concentrate beside such permanent pools, which are the places selected by natives for villages. It is during the fly-concentration season, which lasts about three months, that the bulk of human trypanosomiasis is believed to be transmitted. Since the degree of concentration is much greater following upon years of very poor rainfall, it follows that after such years man-fly contact is much closer at the village water-holes and that therefore the chances of sleeping sickness spreading are much greater. But after years of exceptionally heavy rainfall pools are far more numerous, fly concentration is much less marked, and conditions are much safer for man; however, they are more dangerous for the nomadic Fulani cattle because fly are ubiquitous in the streams, along which the cattle have to find their dry-season grazing.

The fly population becomes minimal in the late dry season, but the expectation of life of those that survive until the rains break is greatest because of the favourable wet-season conditions that lie ahead. If such flies become infected during the period of close man-fly contact, their high expectation of life will facilitate their spreading disease, especially when they re-colonise the streams in the rains and may travel to other villages.

The tsetse population increases enormously in the first part of the rains due to long life associated with intermediate saturation deficits, and a rapid reproduction rate associated with a very high mean temperature. The fly population decreases steadily throughout the dry season due to short life associated with very high saturation deficit, a low breeding rate associated with the low temperature of the mid-dry season, and culminating in a heavy mortality due to dangerously high maximum temperatures before the rains break.

At favourable seasons females can live up to six months in nature and males nearly five months, but the average age attained is far less.

Optimal conditions for the fly community are associated with a mean temperature of 77 °F. (25 °C.) and a relative humidity of 83 per cent.

On ecological grounds control measures should be started when the rains are due and the fly population minimal, and continued throughout the recovery season, after which extermination of any survivors can be left to natural factors associated with the dry season reduction period.

From dissections of wild flies it was found that infection with *Trypanosoma vivax* is least in the cold dry season, and becomes maximal in the heavy rains when the oldest tsetse are found.

G. palpalis can thrive on a diet of virtually only baboon, duiker, monitor lizard and possibly monkey blood; it experiences definite hunger at the height of the heavy rains when the fringing forest is inundated.

A comparative study of the fly population in each 100 yards of stream showed that the following features are essential to a permanent habitat. The presence of good lateral insulation from fire and desiccating wind in the form of a creeper curtain and dense thicket. The existence of good vertical insulation from the sun in the form of a fairly continuous high canopy, and the presence of a free flight-line along the stream-bed to permit travel in search of food. If the fringing forest is narrow the presence of permanent pools is seasonally essential, but the stream banks must be deep so as to aid the vegetation in preventing the dissipation of the microclimate by wind.

These vegetation studies suggested the possibility of an entirely new clearing technique against *G. palpalis*. In the Partial Clearing Technique in general use the undergrowth and low branching trees only are removed, the hot dry Harmattan wind gains entry, the ecoclimate and microclimates are destroyed, and the tsetse is eradicated; the disadvantage of the method is the need for annual reslashing of the regenerated vegetation. The proposed new method, known as Obstructive Clearing, consists in sparing the thicket and creepers, but felling the trees of the canopy into the stream-bed, so as to destroy the vertical insulation and obstruct the flight-line. This should force the fly to seek for food in the adjacent woodland savannah where seasonally the climate is too severe. If the method succeeds there will be no need for annual maintenance, as the production of a low, impenetrable tangle is the desired objective. So far, two miles of obstructive clearing have been carried out. It has been found that the initial clearing costs are considerably less and that the fly population is enormously reduced, but it is too soon to say whether extermination will be achieved.

* * * *

Mr. A. H. Parker has studied in great detail the stimuli governing the selection of larviposition sites by *G. palpalis*. Wooden trays containing dry sand are attractive but not empty trays; this attraction to sand is greatly diminished in darkness, but does not disappear. Since the sand used was somewhat darker in colour than the concrete floor, part of the floor was covered in dark cloth; the response to the sand trays in that part of the room then completely disappeared.

This suggestion of a long-range visual stimulus was confirmed by the discovery that any black object is attractive, even a piece of black paper on the floor; the attractiveness of the black object is enhanced if it is of a shape that produces a nook. Shaded trays produced more pupae than unshaded, especially if shaded by a horizontal object, rather than a vertical. Larviposition is greatest where there is a combination of horizontal shading over soil or sand.

Soil consisting of large particles (0·07–0·10 inches diameter) is more attractive than fine soil (up to 0·01 inch), owing to its rougher texture. Caked soil is not less attractive than loose soil, providing the surfaces are of similar texture. The attractive feature is the roughness of the surface, not the movability of the particles. In the selection of soil, a short-range tactile response is believed to be involved. Both damp and water-logged soils, although darker in appearance than dry soil are less attractive. In the rains the female has perforce to larviposit on wet soil. Since the larva has great difficulty in penetrating such soil, the puparia are usually found on the surface. (Burtt found the same with *G. swynnertoni* in East Africa.)

The female about to larviposit is first attracted visually by dark shade. On reaching the shade she still finds it attractive, as she will rest in it rather than in an adjacent unshaded situation. She will now be much more likely to larviposit if her tactile senses indicate that the soil surface is rough, uneven and dry.

These results are being written up by Mr. Parker for publication.

* * * *

The discovery that the apparently rare species of forest tsetse of the *fusca* group can be found readily by searching for them on saplings and creeper stems has opened up new fields of research (Nash & Davey, 1950). This technique, by enabling the taking of specimens in considerable numbers, has been responsible for the discovery that *G. medicorum* Aust. can be heavily infected with the trypanosomes which are pathogenic to cattle; it has also enabled studies to be made on such common species as *G. morsitans* Westw. whilst the insects are inactive and at rest on trees in the savannah (Nash, 1952). Whereas gorged *G. morsitans* tend to rest low down on tree trunks in the vertical plane with the head up, intermediate and hungry flies tend to rest on the under side of horizontal branches, often at a great height, where they can readily see any passing hosts and where incidentally they may receive some protection from aerial spraying and dusting.

In 1953 a field station was built by Mr. W. A. Page in Southern Nigeria at the junction of the forest belt and savannah. The site is noteworthy, in that the following species of tsetse can be found within two or three miles of the laboratory. *G. fusca* (Wlk.), *G. nigrofusca* Newst., *G. medicorum*, *G. tabaniformis* Westw., *G. pallicera* Big., *G. palpalis*, *G. tachinoides* Westw., and *G. longipalpis* Wied. Since extremely little critical work has been done on six of these eight species, there will now be a chance to remedy this omission and to evaluate the economic importance of these species.

Much work has been done on the large-scale breeding of *G. palpalis* in the laboratory, and the technique is constantly being improved. It has been found that the flies do much better if fed on goats and not on guineapigs, and that the best fertilisation is achieved if the females are mated in large cages on their third day of life with males that are not less than a week old.

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ZANZIBAR

REVIEW OF ENTOMOLOGICAL WORK FROM 1948 TO 1954

There was no entomologist stationed in Zanzibar during 1948 and 1949. Mr. M. J. Way was seconded from Rothamsted and arrived in Zanzibar in May 1950, and undertook valuable work in connection with Aphids, scale-insects and mealybugs which at that time were considered possible carriers of the presumed sudden-death " virus " in cloves. Later it was shown that sudden-death was due to a pathogenic fungus. Mr. Way undertook to investigate the so-called nutfall and gumming disease of coconuts for the Agriculture Department. He discovered this was due to a Coreid bug.* Mr. Way showed that *Oecophylla longinoda* protected the palms against the Coreid but other ants, such as *Pheidole* sp., *Anoplolepis longipes* and *Crematogaster* sp. were antagonistic to *Oecophylla*, and failed to control the bug. Mr. Way returned to Rothamsted in December 1951, and Dr. V. L. Vanderplank took over the work in November 1951.

Dr. Vanderplank discovered that three other pests could also cause either nutfall and, or gummosis. There is a weevil, *Diocalandra frumenti*, moth larvae, *Lamoria* sp., and an ant, *Polyrhachis schistacea* var. *regulosa.* Extensive ecological studies, and fair-sized spraying trials of plots up to 600 acres, both from the ground and the air, have been carried out.

Considerable promise has been obtained with a new DDT insecticidal formulation, which incorporates a synthetic resin. This is effective against the Coreid bug, *D. frumenti*, *Lamoria* sp. and antagonistic ants such as *Pheidole* sp., *A. longipes* and *Crematogaster* sp.; it does not, however, do much harm to *Oecophylla* sp., which has increased as much as 37% in the most frequently sprayed plot (8 acres). It has no effect on the honey-bee populations, nor on the various Coccinellid predators of scales, mealybugs and similar insects.

The major difficulties encountered are in the application of the insecticide, due to the height of the palms, and the windy conditions that mostly prevail in Zanzibar, also the difficulty of spraying in areas where there are other crops or coral outcrops beneath the palms.

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* [This species which has hitherto been referred to in the literature as *Theraptus* sp. is now known not only to be a new species but to belong to a new genus, the descriptions of which are shortly to be published by Mr. E. S. Brown. *Ed.*]

Commonwealth Institute of Entomology

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